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**WIND TUNNEL INVESTIGATION OF THE  
TRANSONIC STATIC STABILITY CHARACTERISTICS  
OF A BLUFF BODY SHAPE WITH VARIOUS  
AFTERBODY-STABILIZER CONFIGURATIONS**

**G. R. Gomillion**

**ARO, Inc.**

**May 1972**

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## FOREWORD

The work reported herein was sponsored by the Air Force Armament Laboratory (DLGC/Mr. C. Butler), Air Force Systems Command (AFSC), Eglin Air Force Base, Florida, under Program Element 63601F, System 670A.

The test results presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract F40600-72-C-0003. The test was conducted from February 16 to 17, 1972, under ARO Project No. PT0258. The manuscript was submitted for publication on April 13, 1972.

This technical report has been reviewed and is approved.

George F. Garey  
Lt Colonel, USAF  
AF Representative, PWT  
Directorate of Test

Frank J. Passarello  
Colonel, USAF  
Acting Director  
Directorate of Test

**ABSTRACT**

An investigation was conducted in the Aerodynamic Wind Tunnel (4T) to obtain the static stability characteristics of a bluff body shape with various afterbody-stabilizer configurations. Data are presented for a Mach number range from 0.6 to 1.3 over an angle-of-attack range from -2 to 28 deg. For all configurations tested, it was found that the static margin was greatest for the configurations having the largest span swept and unswept blade-type fins.

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**NOMENCLATURE**

$A_b$	Model base area, ft <sup>2</sup>
$b$	Fin span, ft
$C_A$	Axial-force coefficient, measured axial force/ $q_\infty S$
$C_{A,b}$	Base axial-force coefficient, $(p_\infty - p_b)A_b/q_\infty S$
$C_\ell$	Rolling-moment coefficient, rolling moment/ $q_\infty SD$
$C_m$	Pitching-moment coefficient, pitching moment/ $q_\infty SD$ (moment reference point is 3.00 in. aft of model nose)
$C_N$	Normal-force coefficient, normal force/ $q_\infty S$
$C_n$	Yawing-moment coefficient, yawing moment/ $q_\infty SD$
$C_Y$	Side-force coefficient, side force/ $q_\infty S$
$D$	Model body diameter, 0.1000 ft
$M_\infty$	Free-stream Mach number
$p_b$	Average static pressure at model base, psfa
$p_\infty$	Free-stream static pressure, psfa
$q_\infty$	Free-stream dynamic pressure, psf
$Re$	Reynolds number based on $D$
$S$	Reference area, 0.0079 ft <sup>2</sup>
$X_{cp}$	Center-of-pressure location, $C_m/C_N$ (body diameters from moment reference point, positive when forward of moment reference)
$X_{np}$	Neutral-point location, $(dC_m/dC_N)_{\alpha=0}$ (body diameters from moment reference point, positive when forward of moment reference)



## SECTION I INTRODUCTION

A wind tunnel investigation was conducted in the Aerodynamic Wind Tunnel (4T) to provide static stability characteristics of a bluff body shape with various afterbody-stabilizer configurations. This test is one of a series of tests that have been conducted at AEDC under the Modular Weapon Systems program (Refs. 1, 2, and 3). Tests were conducted for 17 afterbody-stabilizer configurations at Mach numbers from 0.6 to 1.3 for an angle-of-attack range from -2 to 28 deg. The purpose of this report is to document the test and to present the data for all configurations tested.

## SECTION II APPARATUS

### 2.1 TEST FACILITY

Tunnel 4T is a closed-loop, continuous flow, variable density tunnel in which the Mach number can be varied from 0.1 to 1.3. At all Mach numbers, the stagnation pressure can be varied from 300 to 3700 psfa. The test section is 4 ft square and 12.5 ft long with perforated, variable porosity (0.5- to 10-percent open) walls. It is completely enclosed in a plenum chamber from which the air can be evacuated, allowing part of the tunnel airflow to be removed through the perforated walls of the test section. A more thorough description of the tunnel may be found in Ref. 4.

The model support system consists of a pitch sector, boom, and sting which provide a pitch capability from -12 to 28 deg with respect to the tunnel centerline. The center of rotation is at station 108. In addition, a remote-controlled roll mechanism allows roll angle variations of  $\pm 180$  deg. A schematic of the test section showing the location of the test model is shown in Fig. 1 (Appendix). A photograph of the model installation is shown in Fig. 2.

### 2.2 TEST ARTICLES

All of the model configurations have a body maximum diameter of 0.100 ft and a length of 6.83 cal (0.683 ft), with the exception of configuration N10M5A17, which has a length of 7 cal (0.700 ft). Also, all model configurations consist of three components that are shown in Figs. 3 and 4 and which include the afterbody-stabilizer component, the afterbody component, and the nose component. The afterbody-stabilizer component has 17 configurations that are identified in Figs. 3a and 4a. The afterbody-stabilizer configurations have various fin-span-to-body diameter ratios,  $b/D$ , that vary from 1.00 to 4.00 cal. The fins of the afterbody-stabilizer configurations with four fins are oriented  $\pm 45$  deg relative to the pitch plane of the model. The fins of the afterbody-stabilizer configurations with eight fins are symmetrically oriented about the vertical plane such that two fins are located on the top and the bottom of the model. Also, certain afterbody-stabilizer configurations have a 1.00-cal length and the others have a 1.83-cal length. There are two midsection configurations, M4 and M5, which utilize the centerbodies shown in Figs. 3b and 4b. For the M4 configuration, a 4.00-cal length centerbody is used with the 1.83-cal afterbody-stabilizer configurations and a 4.83-cal centerbody is used

with the 1.00-cal afterbody-stabilizer configurations. A 5.00-cal centerbody is used for the M5 configuration. Also shown in Figs. 3b and 4b is the only nose configuration tested (N10) which is a 1.00-cal-length hemisphere-cylinder shape.

## **2.3 INSTRUMENTATION**

In order to accommodate various model base internal diameters and model loads, two different six-component, internal, strain-gage balances were used to measure the overall aerodynamic loads on the model. The largest diameter balance, 0.75 in., was used with the A1, A6, A17, A18, A23, and A24 afterbody-stabilizer configurations, and the 0.40-in.-diam balance was used with the A19, A20, A21, and A22 afterbody-stabilizer configurations. The balance outputs were recorded on an oscillograph for monitoring of model dynamics.

Static pressures on the model base were measured with differential pressure transducers. The base pressure was defined as the average of two pressures measured near the model base at two points located 180 deg apart on the sting.

The model angle of attack was measured with the pitch sector angle-of-attack indicator. These measurements were corrected for support system and balance deflections, resulting from aerodynamic forces and moments, to obtain true model orientation. These measurements were not corrected for any possible flow angularity. Electrical signals from the balances, pressure transducers, and standard tunnel instrumentation systems were processed by the PWT data acquisition system and digital computer for on-line data reduction.

## **SECTION III TEST PROCEDURES**

### **3.1 TEST DESCRIPTION**

Steady-state force and moment data were obtained in Tunnel 4T at Mach numbers from 0.6 to 1.3. For all data presented the total pressure was held constant at approximately 2050 psfa with an approximate 100 psf tolerance, and the nominal variation of Reynolds number and dynamic pressure with Mach number is shown in Fig. 5. Also, for all data presented the tunnel total temperature was held above 100°F. Tunnel conditions were held constant at each Mach number while pitch angle varied, and data were recorded at each selected angle. The pitch range was from -2 to 28 deg. The models were tested with free transition throughout the test program.

### **3.2 PRECISION OF MEASUREMENTS**

The estimated uncertainties associated with tunnel conditions and measured coefficients are as follows:

	<u><math>M_\infty = 0.6</math></u>	<u><math>M_\infty = 0.8</math></u>	<u><math>M_\infty = 1.0</math></u>	<u><math>M_\infty = 1.2</math></u>	<u><math>M_\infty = 1.3</math></u>
$\Delta M_\infty$	$\pm 0.0021$	$\pm 0.0023$	$\pm 0.0039$	$\pm 0.0095$	$\pm 0.0144$
$\Delta q_\infty$	$\pm 2.2$	$\pm 2.2$	$\pm 2.6$	$\pm 3.1$	$\pm 4.5$
$\Delta C_{A,b}$	$\pm 0.010$	$\pm 0.007$	$\pm 0.008$	$\pm 0.015$	$\pm 0.020$

0.75-in.-diam balance

$\Delta C_N$	$\pm 0.032$	$\pm 0.022$	$\pm 0.024$	$\pm 0.026$	$\pm 0.018$
$\Delta C_A$	$\pm 0.026$	$\pm 0.017$	$\pm 0.013$	$\pm 0.012$	$\pm 0.012$
$\Delta C_m$	$\pm 0.084$	$\pm 0.056$	$\pm 0.054$	$\pm 0.050$	$\pm 0.042$
$\Delta C_Y$	$\pm 0.015$	$\pm 0.009$	$\pm 0.006$	$\pm 0.005$	$\pm 0.005$
$\Delta C_n$	$\pm 0.058$	$\pm 0.039$	$\pm 0.030$	$\pm 0.026$	$\pm 0.026$
$\Delta C_l$	$\pm 0.006$	$\pm 0.004$	$\pm 0.003$	$\pm 0.003$	$\pm 0.003$

0.40-in.-diam balance

$\Delta C_N$	$\pm 0.028$	$\pm 0.019$	$\pm 0.019$	$\pm 0.015$	$\pm 0.013$
$\Delta C_A$	$\pm 0.074$	$\pm 0.050$	$\pm 0.040$	$\pm 0.035$	$\pm 0.034$
$\Delta C_m$	$\pm 0.051$	$\pm 0.034$	$\pm 0.026$	$\pm 0.023$	$\pm 0.022$
$\Delta C_Y$	$\pm 0.012$	$\pm 0.009$	$\pm 0.005$	$\pm 0.004$	$\pm 0.004$
$\Delta C_n$	$\pm 0.023$	$\pm 0.016$	$\pm 0.010$	$\pm 0.009$	$\pm 0.009$
$\Delta C_l$	$\pm 0.011$	$\pm 0.007$	$\pm 0.006$	$\pm 0.005$	$\pm 0.005$

The uncertainty quoted for Mach number relates to the variation of Mach number in the vicinity of the test article. The uncertainty for setting and maintaining Mach number during a pitch polar is approximately  $\pm 0.005$  for all Mach numbers. The uncertainty in angle-of-attack measurements is  $\pm 0.1$  deg. The estimated uncertainties in force and moment coefficients are based on 95-percent probability and include possible errors in balance calibration curve fits, and in the case of moment coefficients, transfer of force uncertainties from the balance force system center to the moment reference point (MRP) of the model.

## SECTION IV RESULTS AND DISCUSSION

The measured force and moment data presented have been reduced to coefficient form in the body axes system. The moment reference point (MRP) is located on the centerline 2.5 cal from the model nose. The variations of  $C_N$ ,  $X_{cp}$ ,  $C_A$ ,  $C_{A,b}$ ,  $C_Y$ ,  $C_n$ , and  $C_l$  with  $\alpha$  are presented in Figs. 6 through 11 for each model configuration tested. Also, all  $C_{A,b}$  for all model configurations presented in this report are calculated for the values of  $A_b$  shown in Fig. 4.

A comparison of the aerodynamic characteristics of the configurations with drag plates, N10M4A19 and N10M4A20, is presented in Fig. 6. In general, both configurations produce similar variations in normal-force coefficients for all Mach numbers and angles of attack except for  $\alpha > 20$  deg and  $M_\infty = 0.6$  and  $0.8$ , where the configuration N10M4A20 produces less normal force (Fig. 6a). Figure 6b indicates that the static margin of both

configurations is greatest at  $M_\infty < 1.0$  and that the stability of both configurations is reduced for  $M_\infty \geq 1.0$  with the neutral-point and the center-of-pressure locations moving near or forward of the MRP. The axial-force coefficients are similar for both drag plate configurations with configuration N10M4A20 generally producing the larger values (Fig. 6c). Below  $\alpha = 15$  deg there is no significant side-force coefficient produced by either configuration (Fig. 6e), but for  $\alpha > 16$  deg and particularly for  $M_\infty = 0.6$  and 0.8 there is a very significant side-force coefficient for both configurations that is apparently attributable to an unsymmetrical arrangement of vortices trailing from the model. Also for  $\alpha > 16$  deg the yawing-moment coefficients are significantly affected (Fig. 6f) with the rolling-moment coefficients showing some effect (Fig. 6g).

A comparison for the bomb configurations with different span star fins (N10M4A21,  $b/D = 1.00$  and 1.10) and configuration N10M4A22 is presented in Fig. 7. For all Mach numbers and angles of attack presented the larger span star fin produces the largest normal-force coefficients, the largest static margin, and, generally, slightly larger axial-force coefficients for the configurations compared (Figs. 7a, b, and c). Figure 7b shows that both spans of the star fins produce neutral-point and center-of-pressure locations that remain aft of the MRP for all Mach numbers and angles of attack. Also, Fig. 7b shows that configuration N10M4A22 is unstable except for high angles of attack with the neutral-point location and the center-of-pressure location for low angles of attack well forward of the MRP at all Mach numbers. The apparent unsymmetrical trailing vortex effect is shown in Fig. 7e for  $\alpha > 15$  deg where there is a large and erratic side force for all configurations, particularly at Mach numbers from 0.6 through 1.0. Also, both the yawing-moment coefficient and rolling-moment coefficient are noticeably affected (Figs. 7f and g).

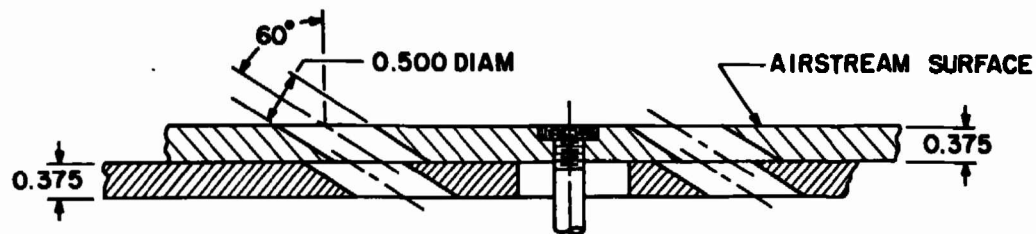
The effects of span on configuration N10M4A18 (Fig. 8), configuration N10M4A23 (Fig. 9), and configuration N10M4A24 (Fig. 10) are generally similar and these configurations are discussed as a single group. All configurations have tapered afterbodies and the blade-type fins. The A18 configurations have swept fins, but configurations A23 and A24 have unswept fins. For all Mach numbers and angles of attack presented, increasing the fin span increases the normal-force coefficient (Figs. 8a, 9a, and 10a), the static margin (Figs. 8b, 9b, and 10b); and the axial-force coefficient (Figs. 8c, 9c, and 10c). The erratic behavior of  $X_{cp}$  at small  $\alpha$  for configuration N10M4A24,  $b/D = 4.00$  (Fig. 10b) is attributed to bending of the fins. A significant permanent set in these fins was produced by aerodynamic loads during testing. Figures 8b, 9b, and 10b show that all neutral-point locations and, with the noted exception, all center-of-pressure locations are well aft of the MRP and generally the  $X_{cp}$  moves forward with increasing angle of attack. The fins of the largest span ( $b/D = 3.46$ ) of configuration N10M4A18 were also observed to have been slightly bent after being tested, and the side force at  $\alpha = 0$  deg shown in Fig. 8e is the apparent result. Also the significantly bent fins of the largest span ( $b/D = 4.00$ ) of configuration N10M4A24 produce a side force at  $\alpha = 0$  deg (Fig. 10e). With the exception of configuration N10M4A18,  $b/D = 2.88$ , there is a very large side force for  $\alpha > 16$  deg at  $M_\infty = 0.6$  and 0.8, and this is again attributable to the unsymmetrical trailing vortices (Figs. 8e, 9e, and 10e). The trends in side force at high  $\alpha$  are generally also reflected in the yawing-moment and rolling-moment coefficients.

A comparison for two finned configurations (N10M4A1 and N10M4A6) and a finless configuration N10M5A17 is presented in Fig. 11. As expected configuration N10M5A17 produces less normal-force coefficient (Fig. 11a) and is less stable than either finned configuration (Fig. 11b). Also configuration N10M4A1 produces more normal force and static margin than configuration N10M4A6 (Figs. 11a and b). In general the variations in axial-force coefficients (Fig. 11c) are similar for all configurations, and a measurable increase in axial force is produced by the fins. Figures 11e, f, and g show that for  $\alpha > 15$  deg at  $M_\infty = 0.6$  and  $0.8$ , significant side force, yawing moment, and rolling moment are evident for configurations N10M4A1 and N10M4A6, but not for N10M5A17. This suggests that an interaction between the previously mentioned vortices and the fins is responsible.

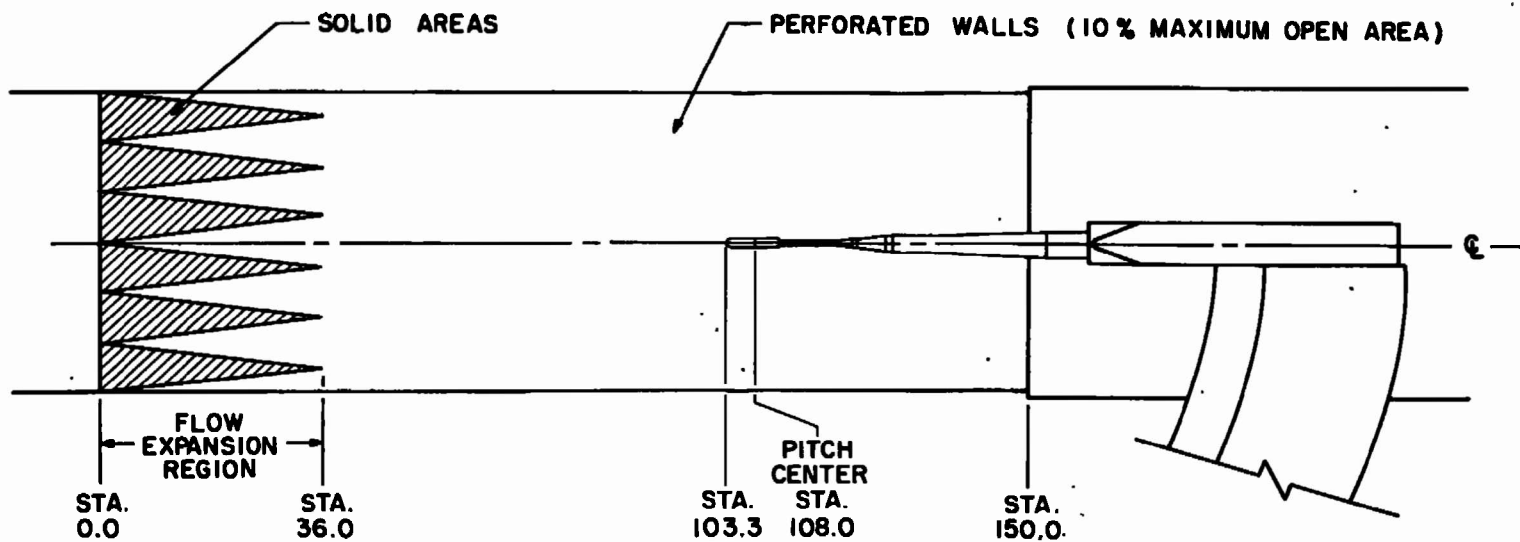
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1. Caldwell, R. L. and Gomillion, G. R. "Wind Tunnel Investigation of the Transonic Static Stability Characteristics and Scale Effects of Various Bomb Configurations." AEDC-TR-71-21 (AD880562L), February 1971.
2. Caldwell, R. L. "Static and Dynamic Stability Investigation of Bombs for the Modular Weapon System at Transonic Mach Numbers." AEDC-TR-71-65 (AD882494L), April 1971.
3. Anderson, C. F. and Henson, J. R. "Aerodynamic Characteristics of Several Bluff Bodies of Revolution at Mach Numbers from 0.6 to 1.5." AEDC-TR-71-130 (AD885911), AFATL-TR-71-82, July 1971.
4. Test Facilities Handbook (Ninth Edition). "Propulsion Wind Tunnel Facility, Vol. 4." Arnold Engineering Development Center, July 1971.

**APPENDIX  
ILLUSTRATIONS**



TYPICAL PERFORATED WALL CROSS SECTION



TUNNEL STATIONS AND DIMENSIONS IN INCHES

Fig. 1 Sketch of Model Installation

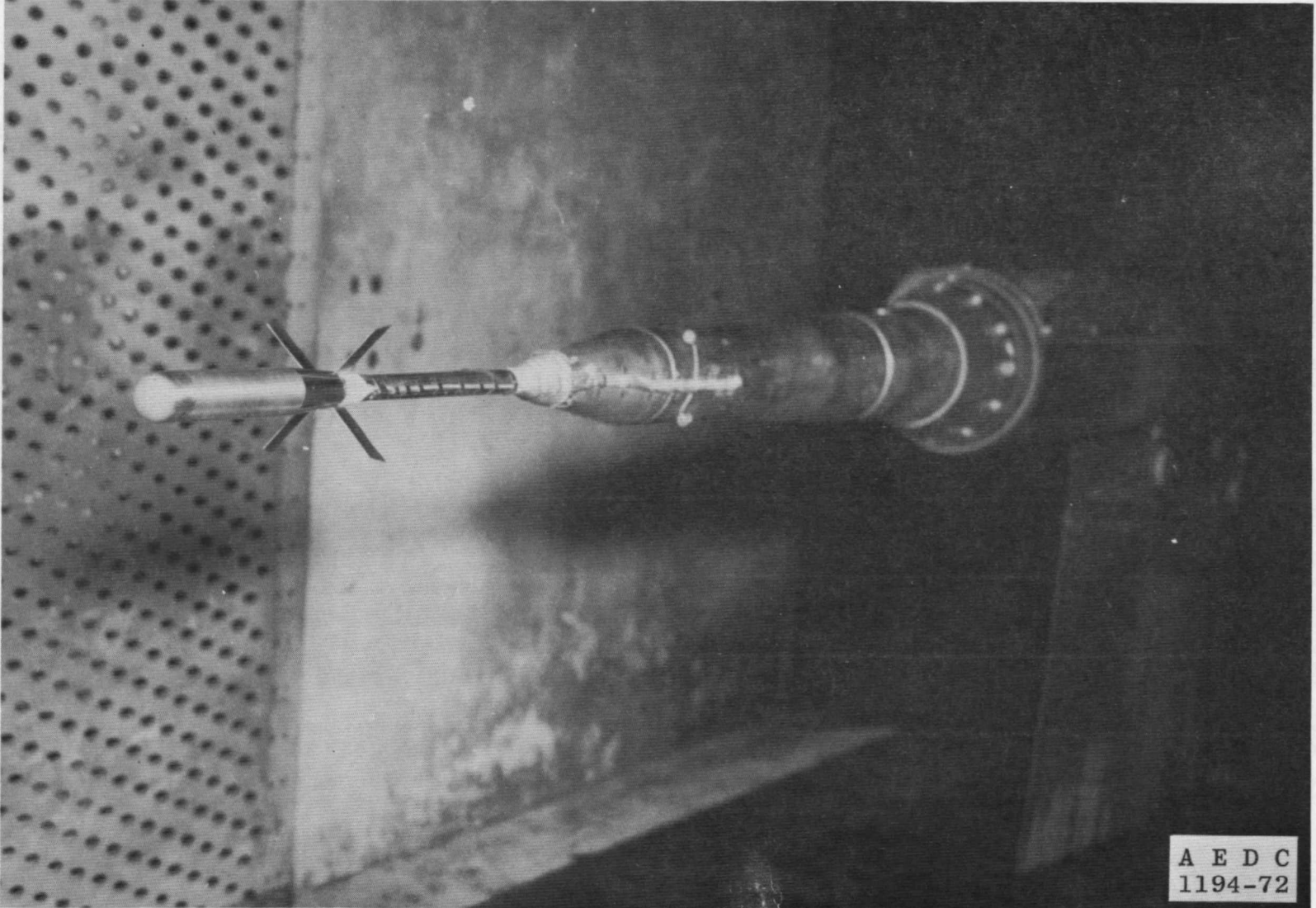
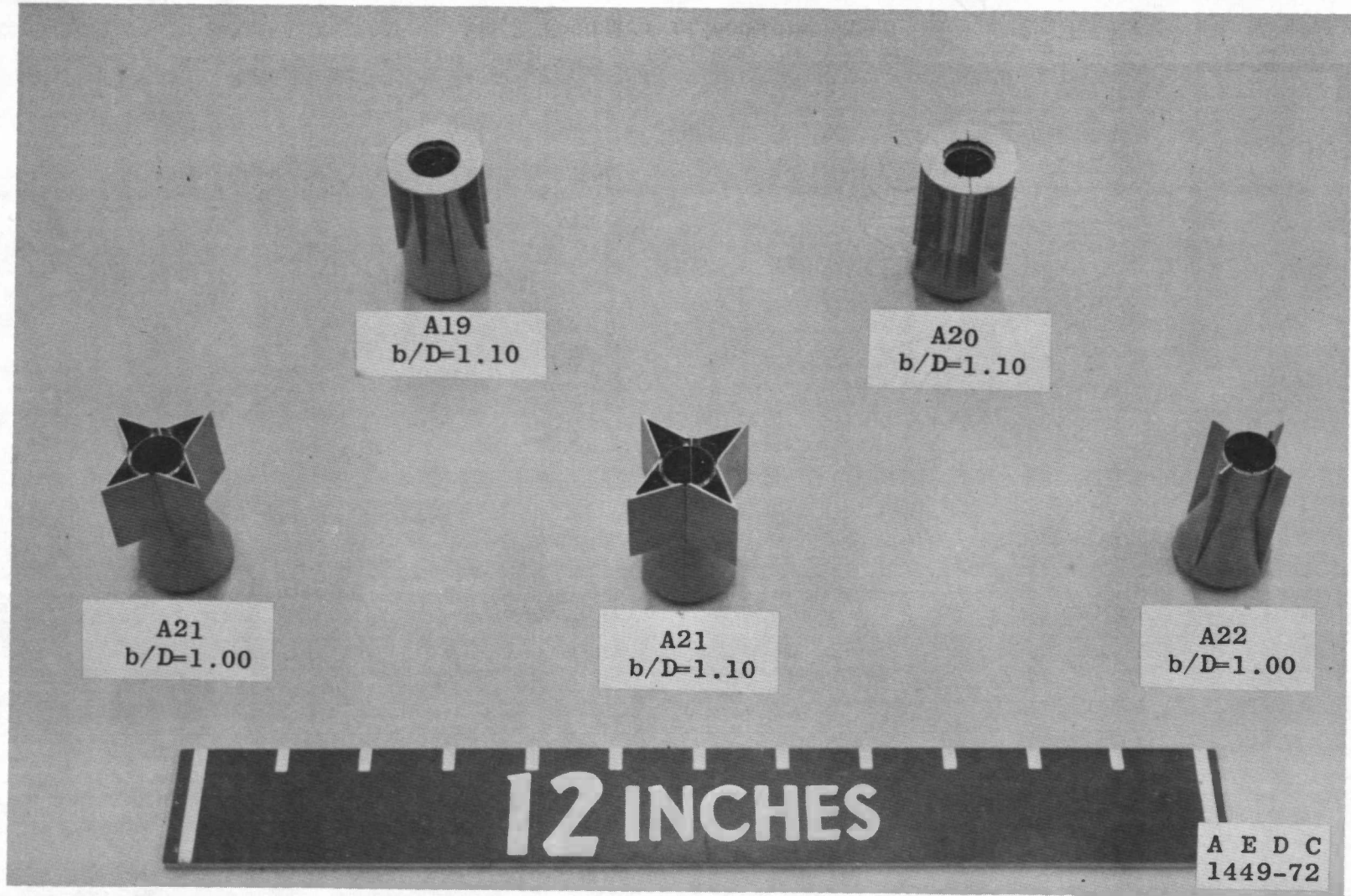


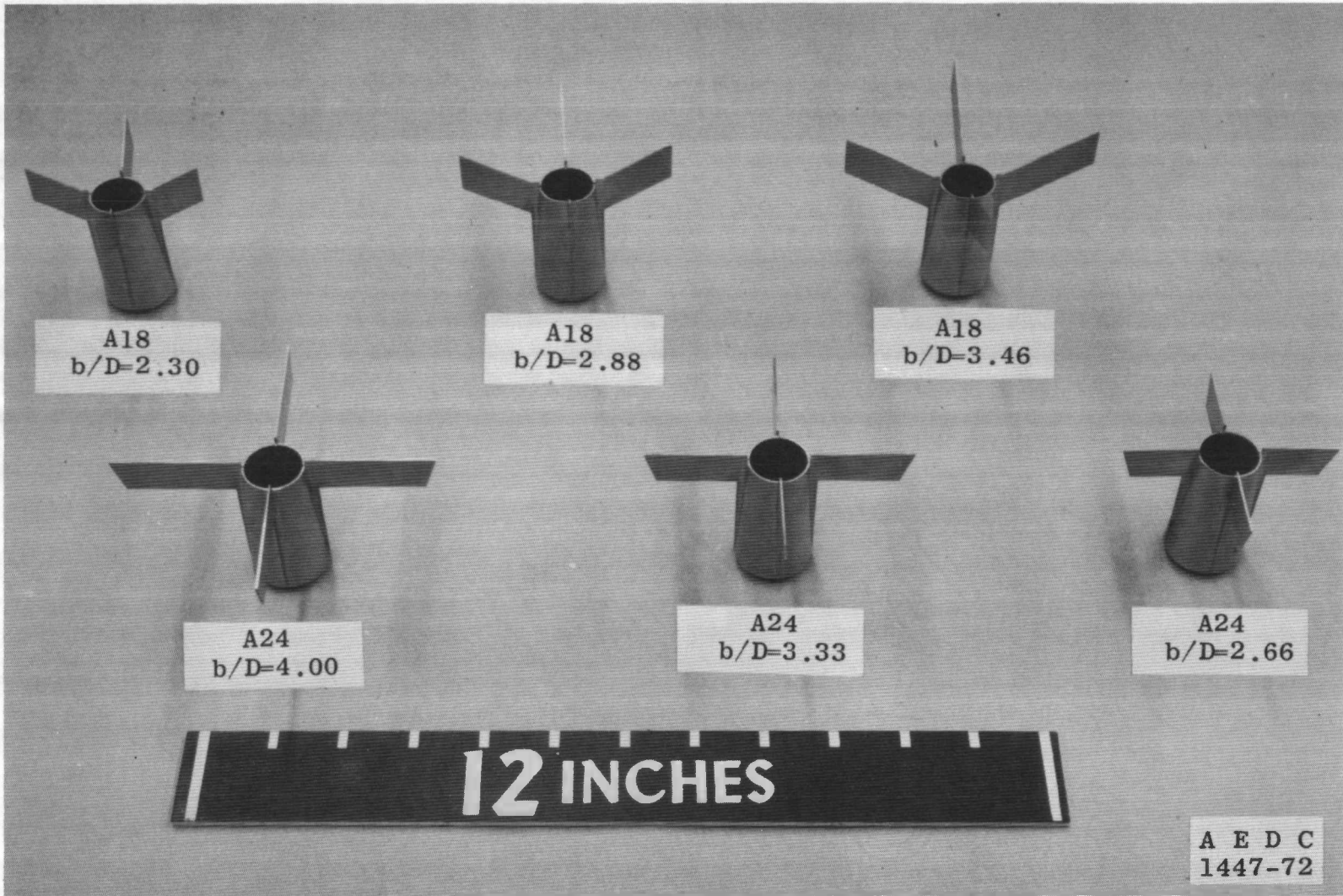
Fig. 2 Photograph of Model Installation

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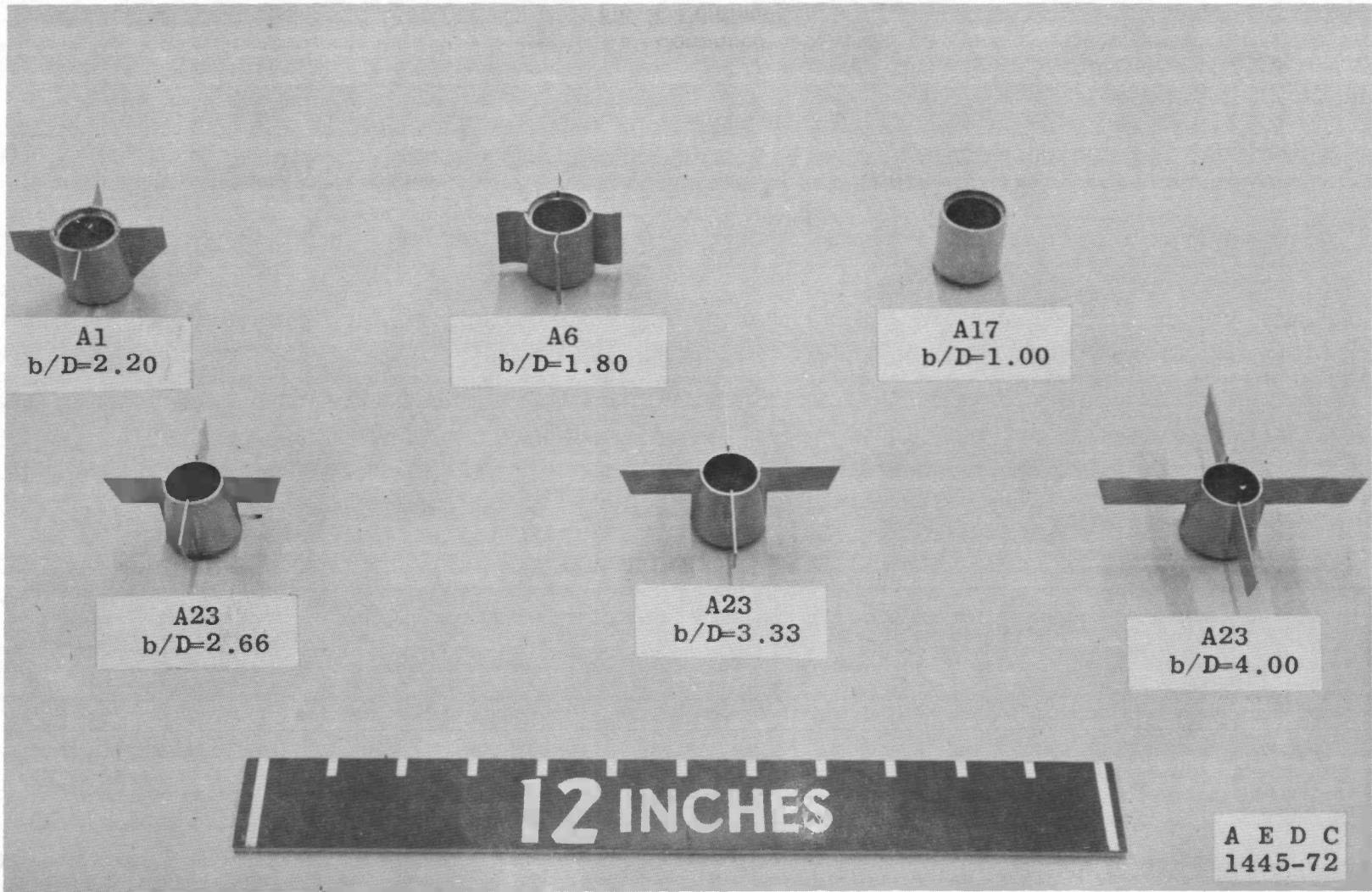


a. Afterbody-Stabilizer Components  
Fig. 3 Photographs of Model Components

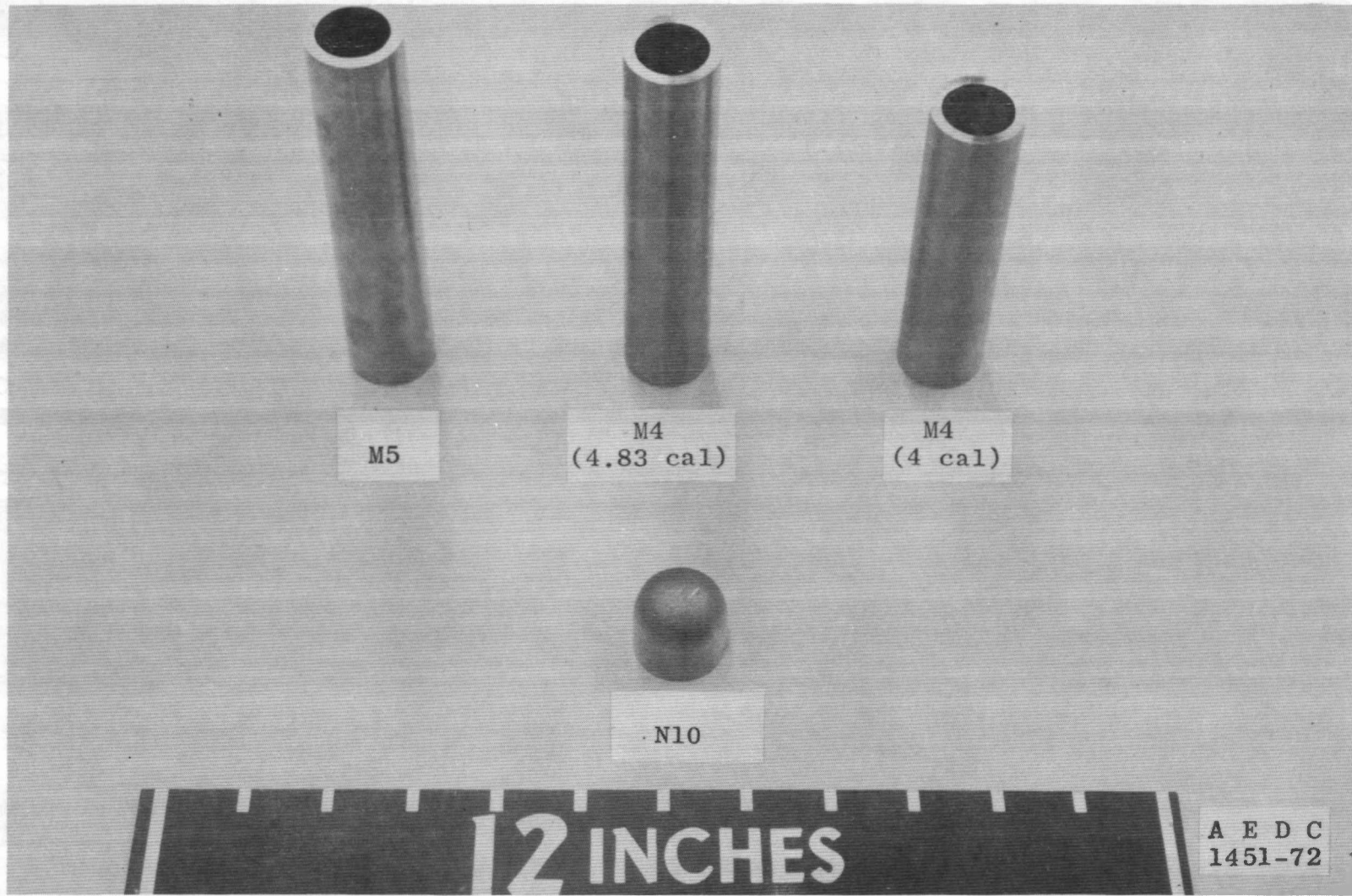


12

a. Continued  
Fig. 3 Continued



a. Concluded  
Fig. 3 Continued



M5

M4  
(4.83 cal)

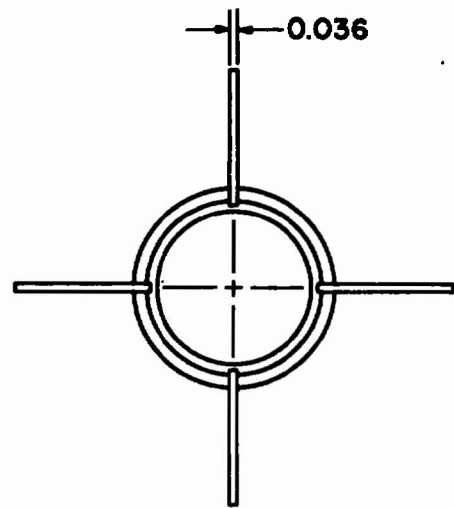
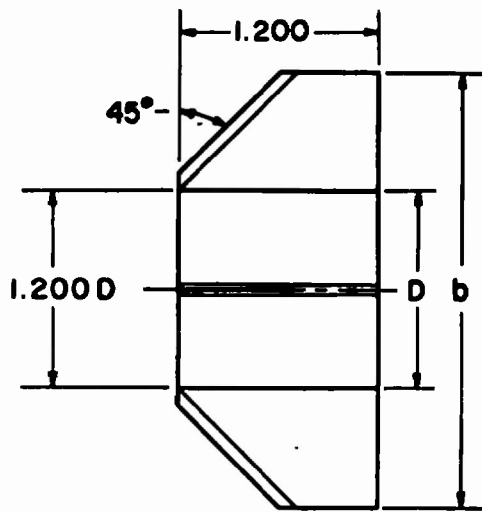
M4  
(4 cal)

N10

12 INCHES

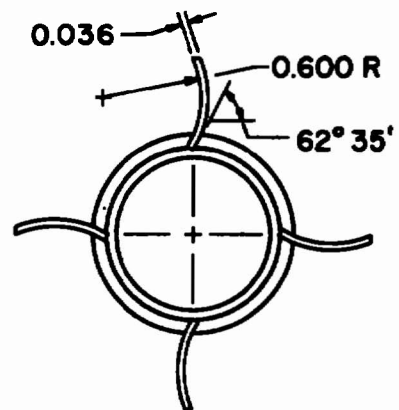
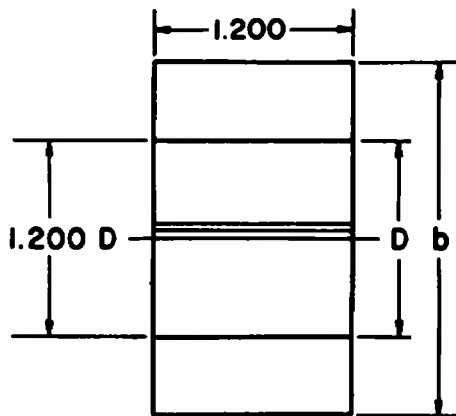
A E D C  
1451-72

b. Nose and Centerbody Components  
Fig. 3 Concluded



$b/D = 2.20 \quad A_b = 0.0079 \text{ ft}^2$

**A1**

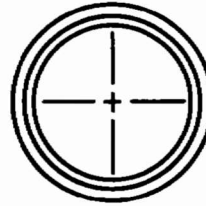
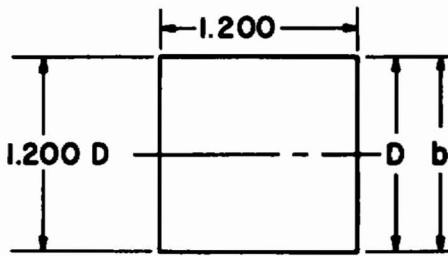


$b/D = 1.80 \quad A_b = 0.0079 \text{ ft}^2$

**A6**

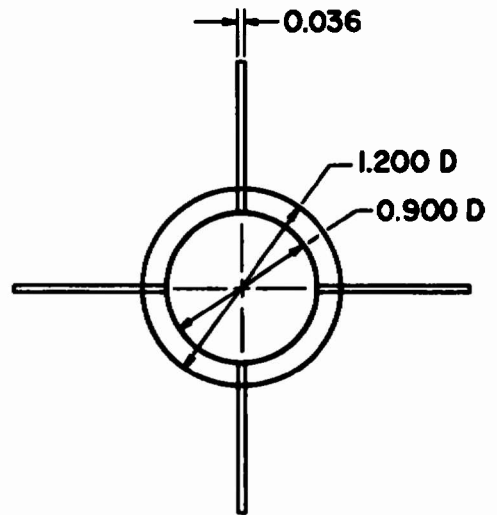
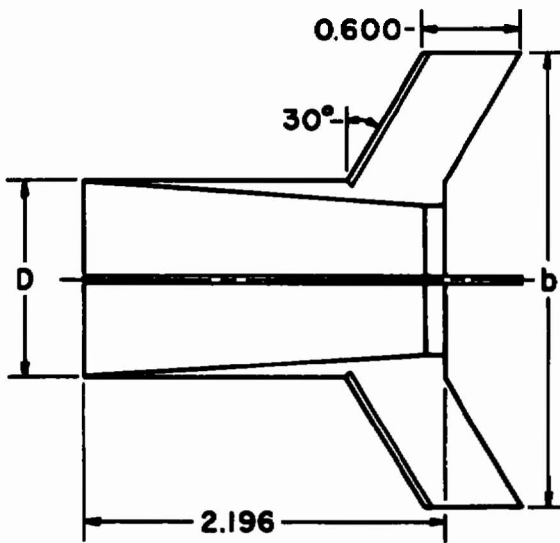
**DIMENSIONS IN INCHES**

**a. Afterbody-Stabilizer Components**  
**Fig. 4 Dimensional Sketches of Model Components**



$b/D = 1.00 \quad A_b = 0.0079 \text{ ft}^2$

**A17**

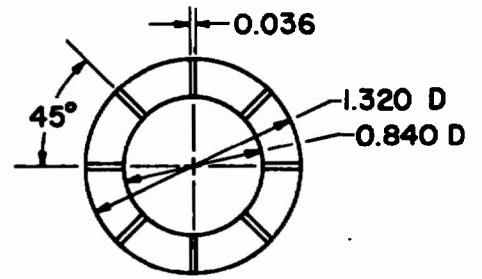
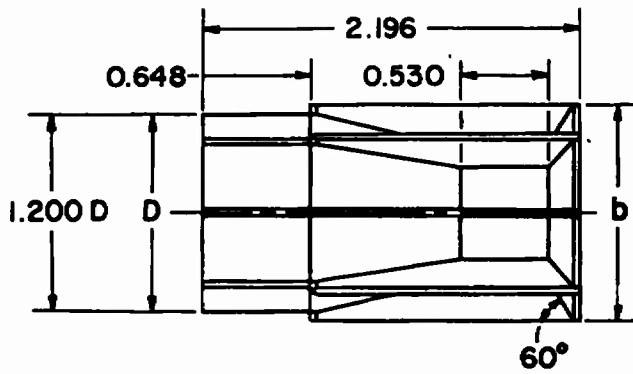


$b/D = 2.30, 2.88, 3.46 \quad A_b = 0.0044 \text{ ft}^2$

**A18**

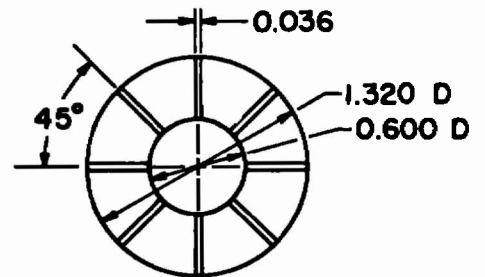
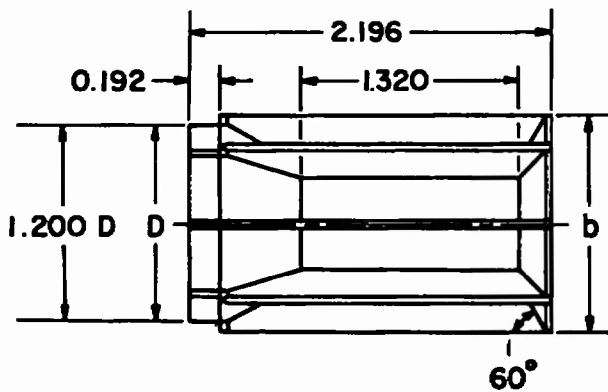
**DIMENSIONS IN INCHES**

a. Continued  
Fig. 4 Continued



$b/D = 1.10$       $A_b = 0.0095 \text{ ft}^2$

A19

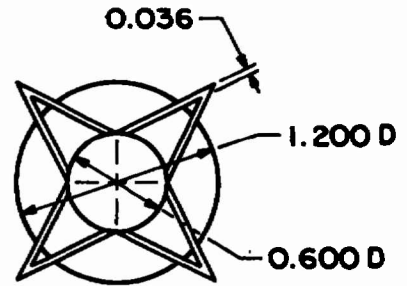
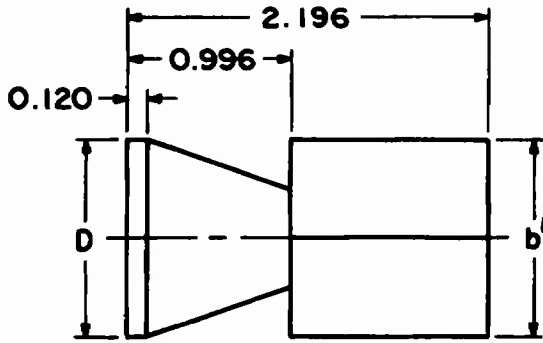


$b/D = 1.10$       $A_b = 0.0095 \text{ ft}^2$

A20

DIMENSIONS IN INCHES

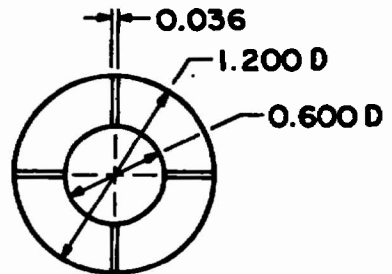
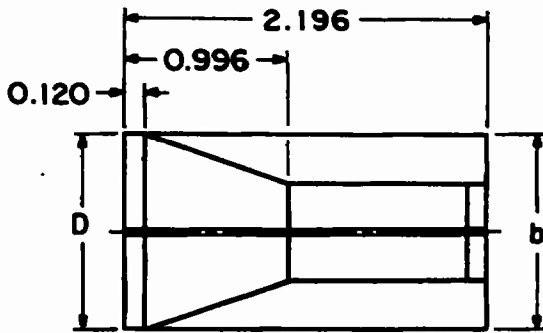
a. Continued  
Fig. 4 Continued



$b/D = 1.00, 1.10$

$A_b = 0.0026 \text{ ft}^2$

A21



$b/D = 1.00$

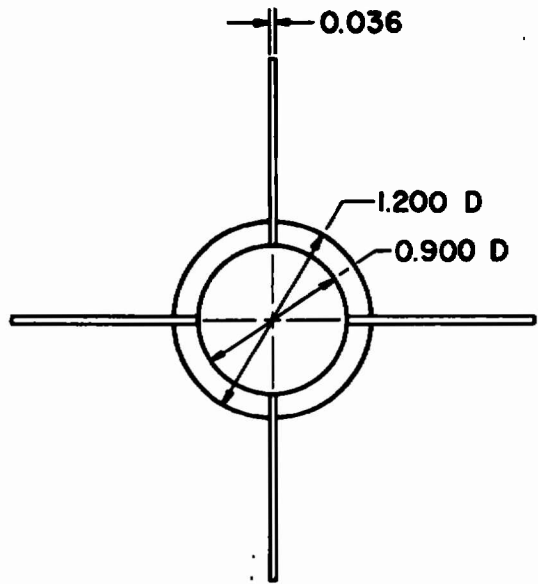
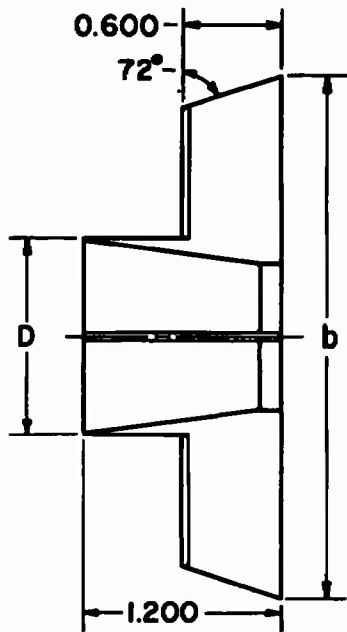
$A_b = 0.0026 \text{ ft}^2$

A22

DIMENSIONS IN INCHES

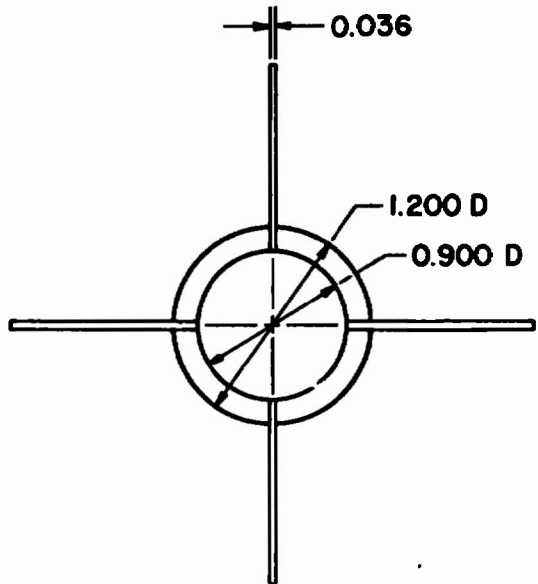
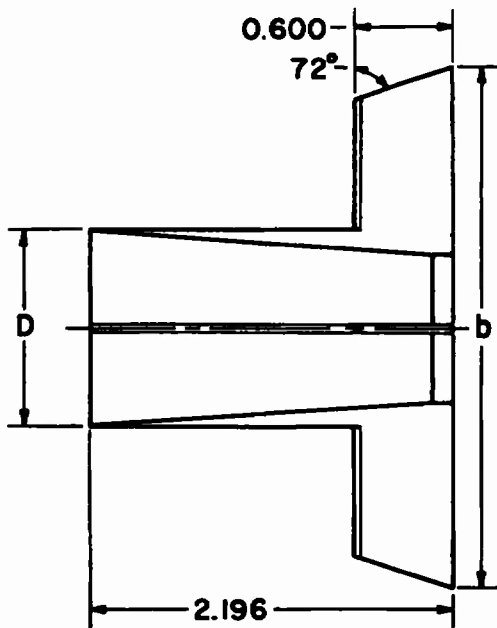
a. Continued  
Fig. 4 Continued





$b/D = 2.66, 3.33, 4.00$      $A_b = 0.0044 \text{ ft}^2$

A23

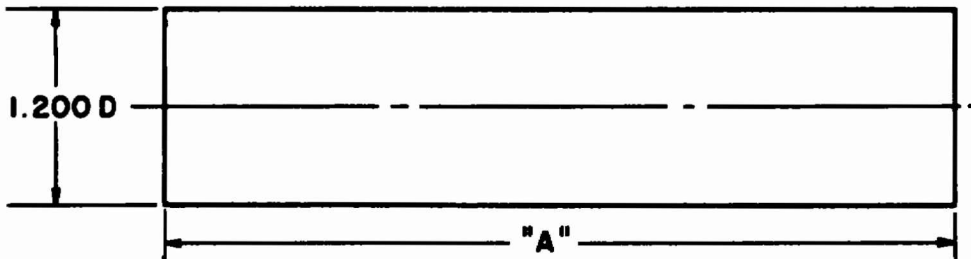
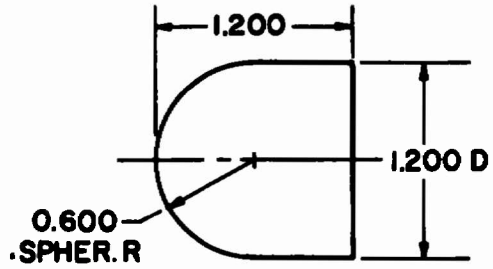


$b/D = 2.66, 3.33, 4.00$      $A_b = 0.0044 \text{ ft}^2$

A24

DIMENSIONS IN INCHES

a. Concluded  
Fig. 4 Continued



MIDSECTION	AFTERBODIES	"A"
M4	A18, A19, A20, A21, A22, A24	4.800
M4	A1, A6, A23	5.976
M5	A17	6.000

ALL DIMENSIONS IN INCHES

b. Nose and Centerbody Components  
 Fig. 4 Concluded

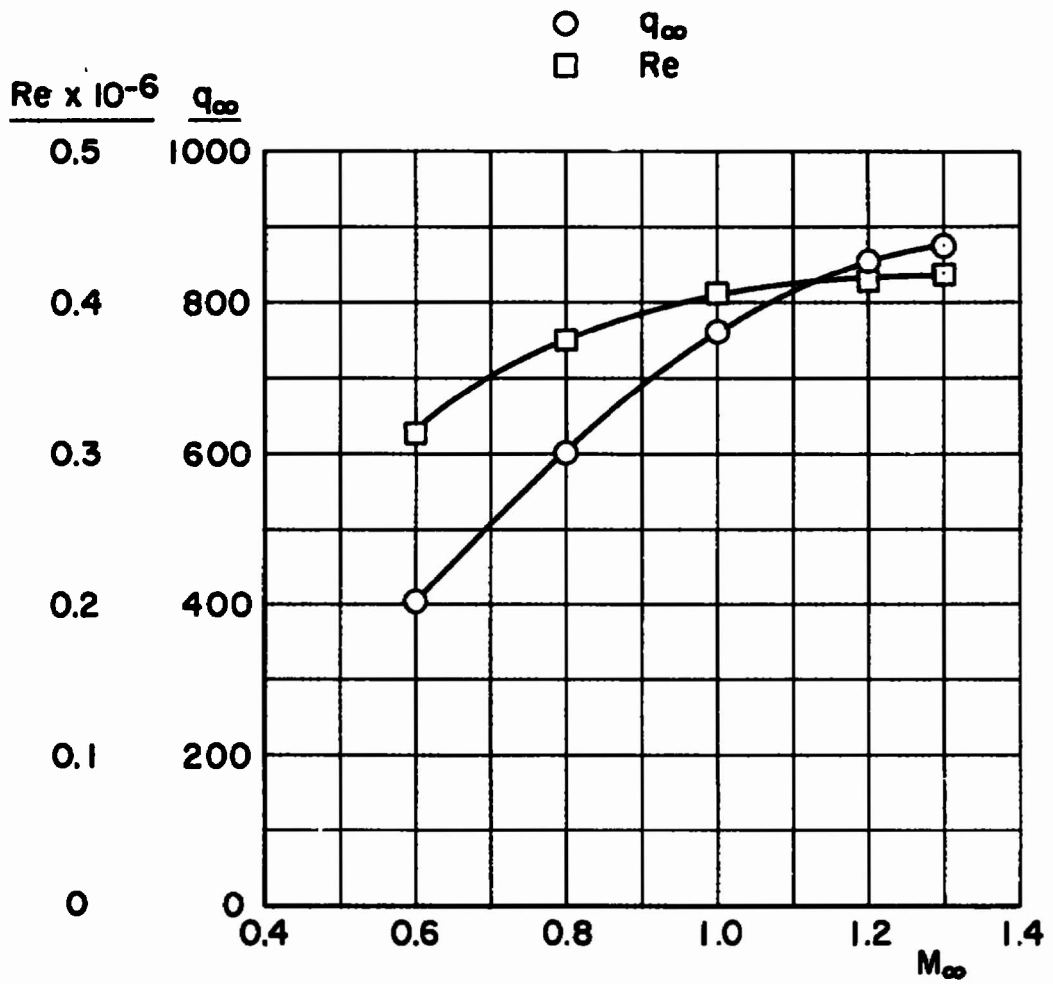
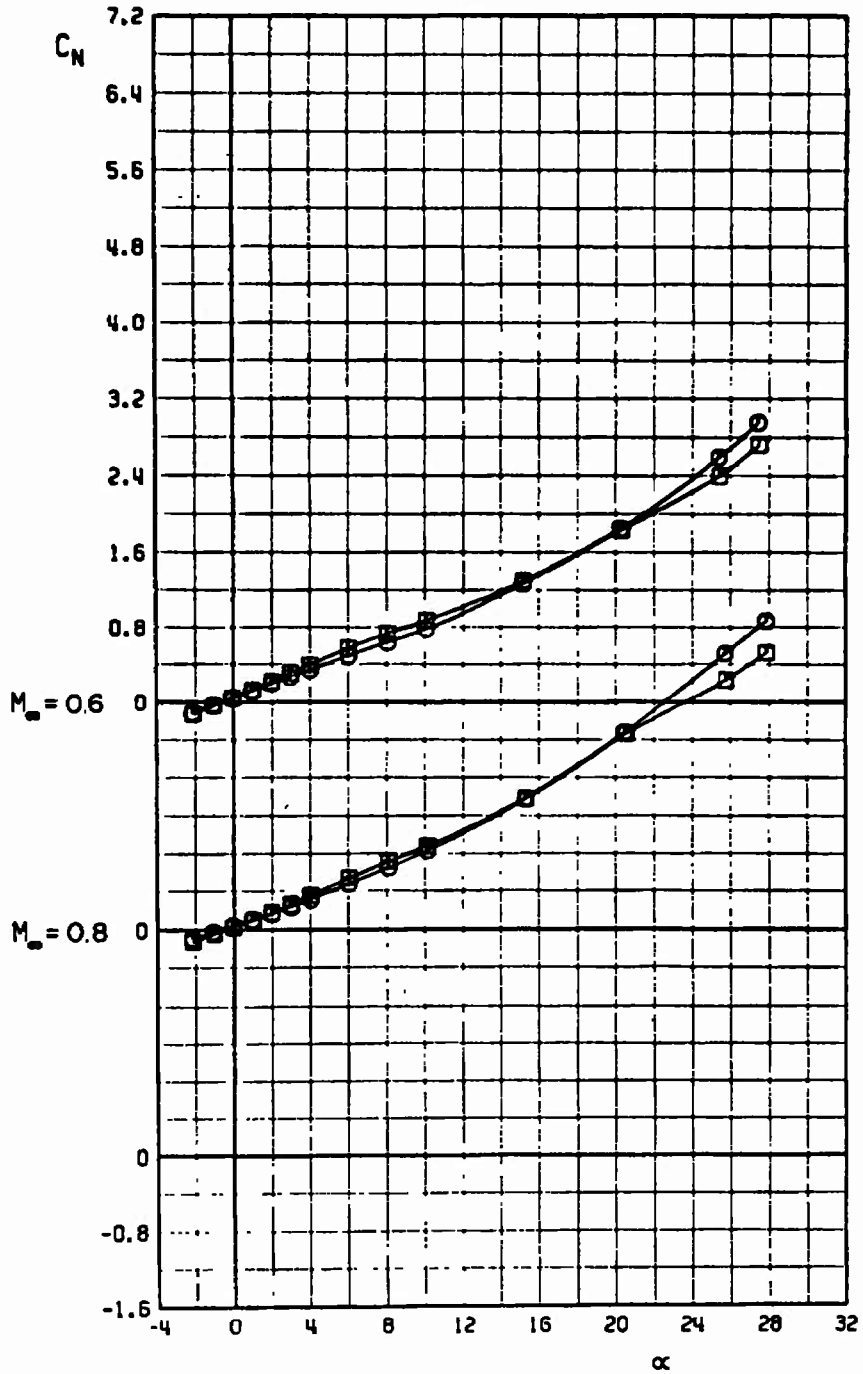


Fig. 5 Nominal Variation of Reynolds Number and Dynamic Pressure with Mach Number

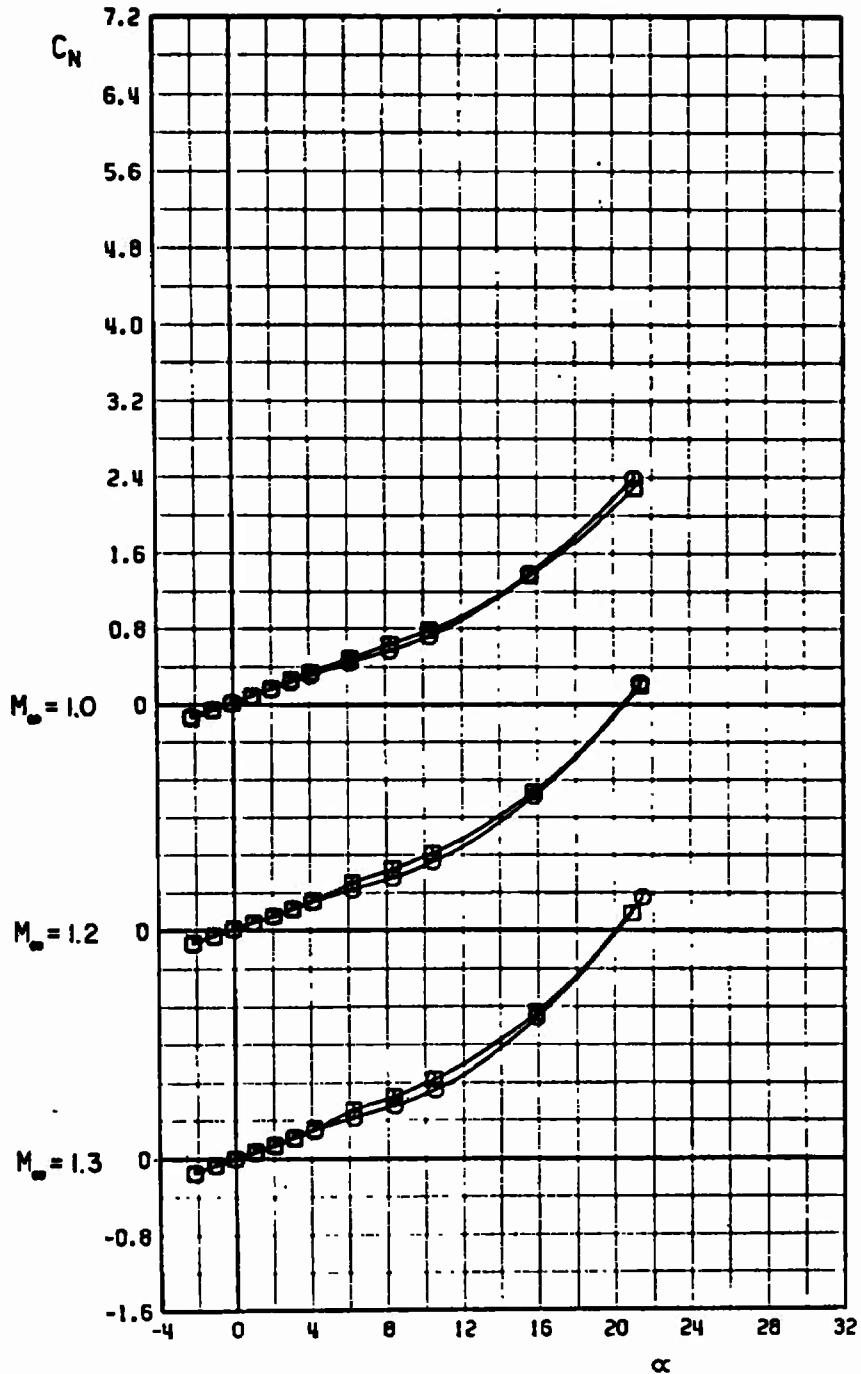
	CONFIGURATION	b/D
○	N10 M4 A19	1.10
□	N10 M4 A20	1.10



a.  $C_N$  versus  $\alpha$

Fig. 6 Aerodynamic Coefficients of Configurations N10M4A19, b/D = 1.10 and N10M4A20, b/D = 1.10

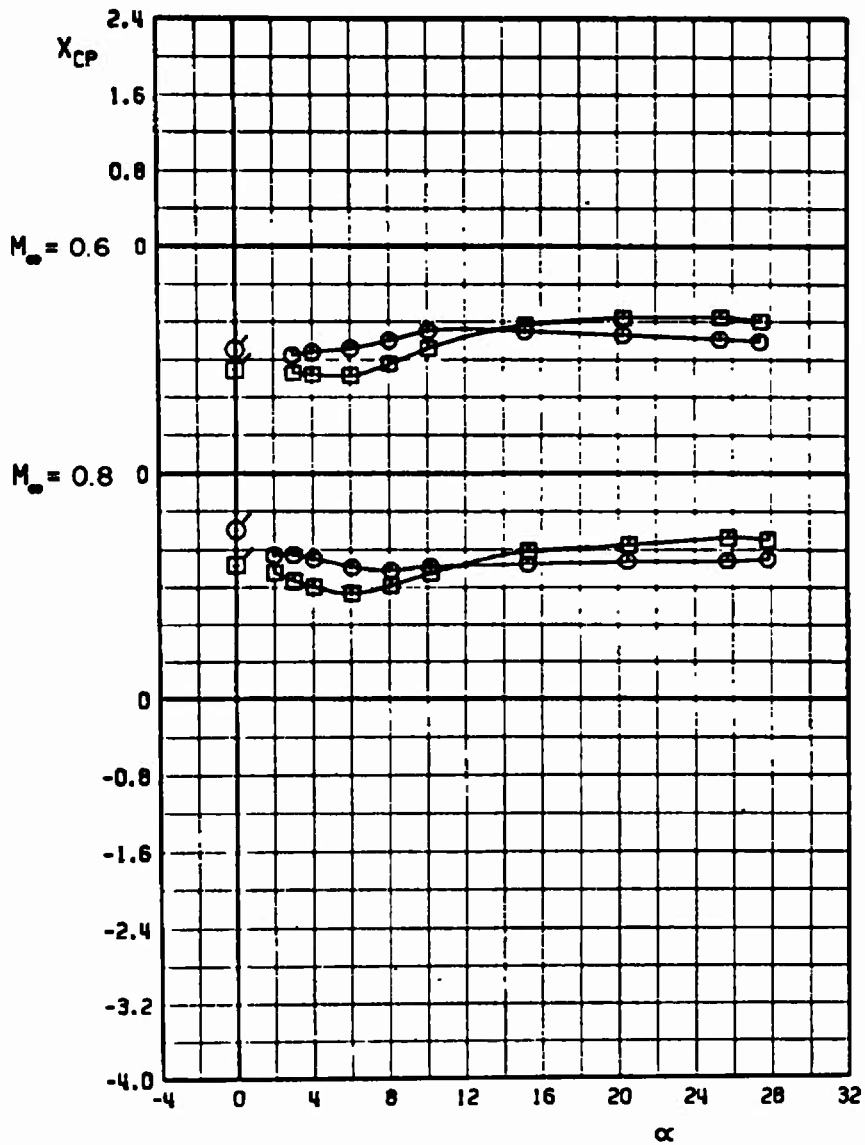
	CONFIGURATION	b/D
○	N10 M4 R19	1.10
□	N10 M4 R20	1.10



a. Concluded  
Fig. 6 Continued

	CONFIGURATION	b/D
○	N10 M4 A19	1.10
□	N10 M4 A20	1.10

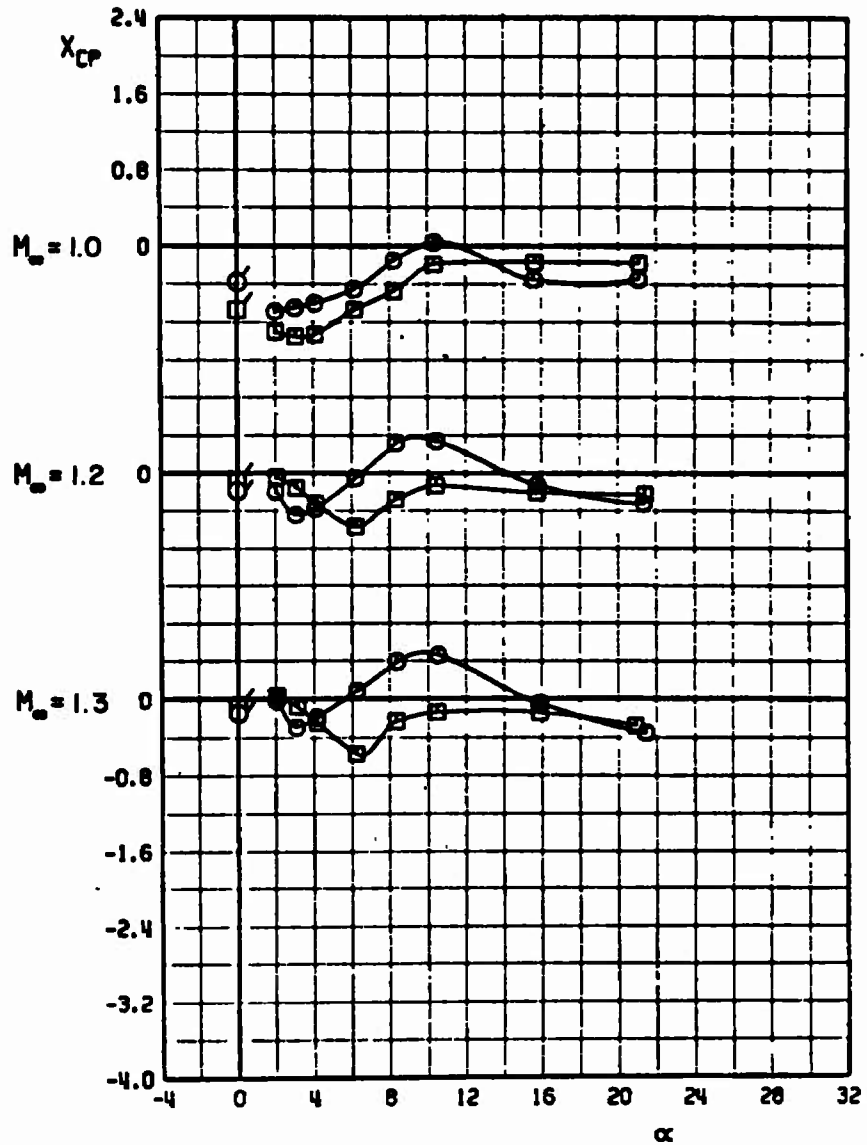
FLAGGED SYMBOLS DENOTE NEUTRAL-POINT LOCATIONS



b.  $X_{CP}$  versus  $\alpha$   
 Fig. 6 Continued

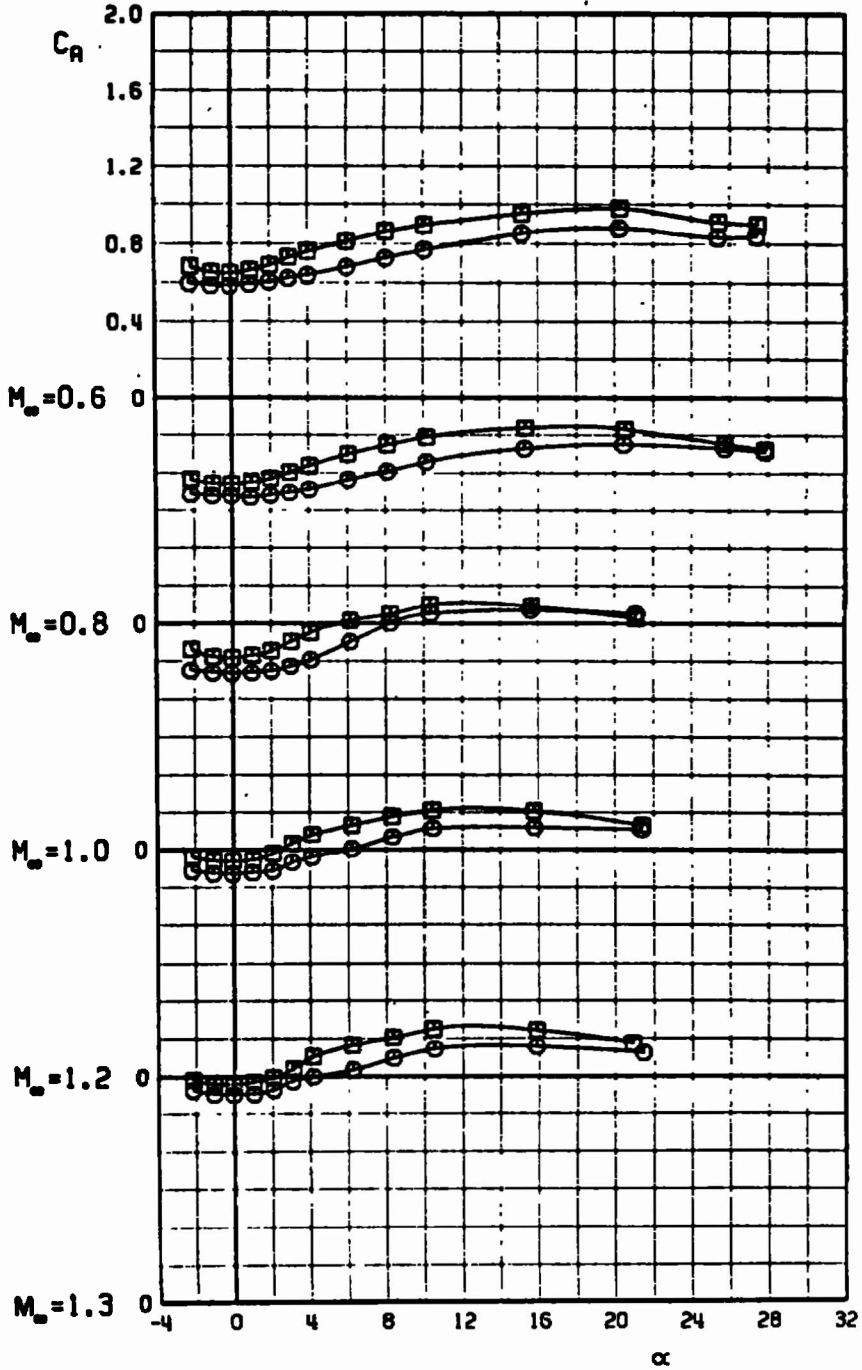
	CONFIGURATION	b/D
○	N10 M4 R19	1.10
□	N10 M4 R20	1.10

FLAGGED SYMBOLS DENOTE NEUTRAL-POINT LOCATIONS



b. Concluded  
Fig. 6 Continued

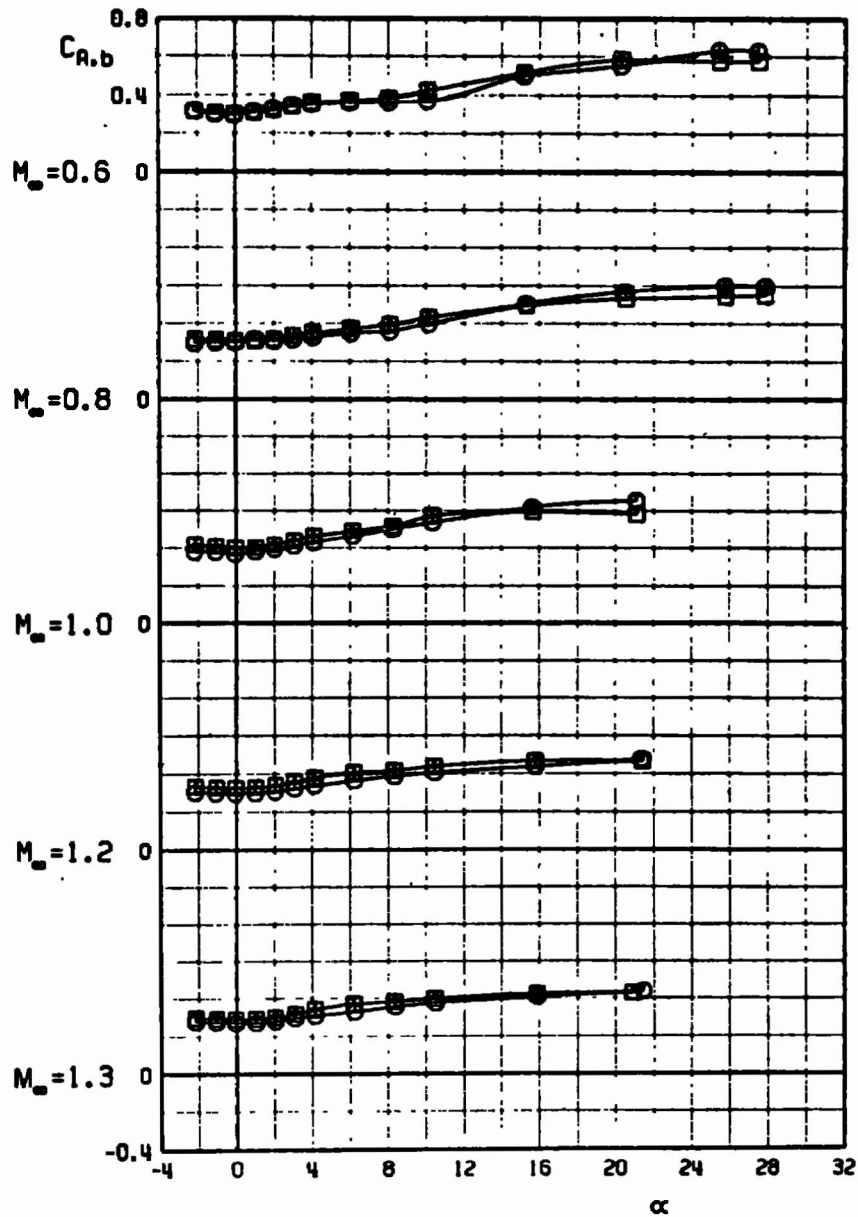
	CONFIGURATION	b/D
○	N10 M4 R19	1.10
□	N10 M4 R20	1.10



c.  $C_A$  versus  $\alpha$   
 Fig. 6 Continued

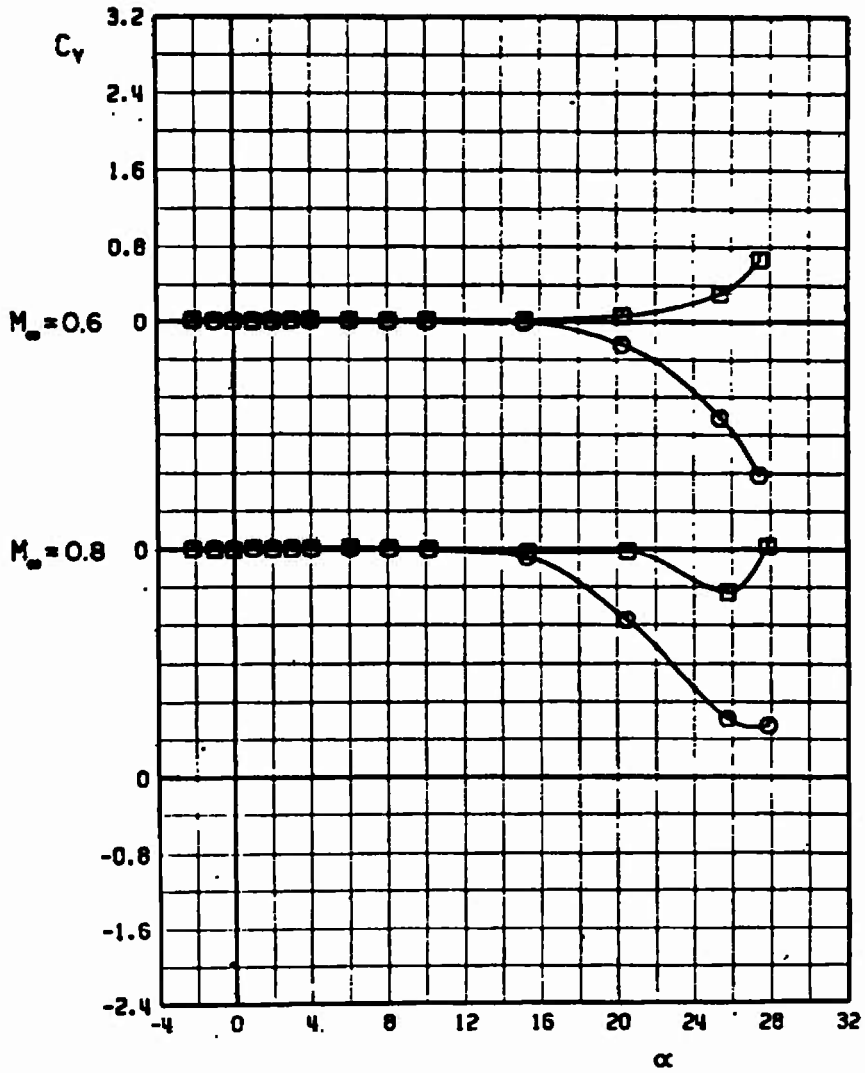


○ CONFIGURATION b/D  
 N10 M4 R19 1.10  
 □ N10 M4 R20 1.10



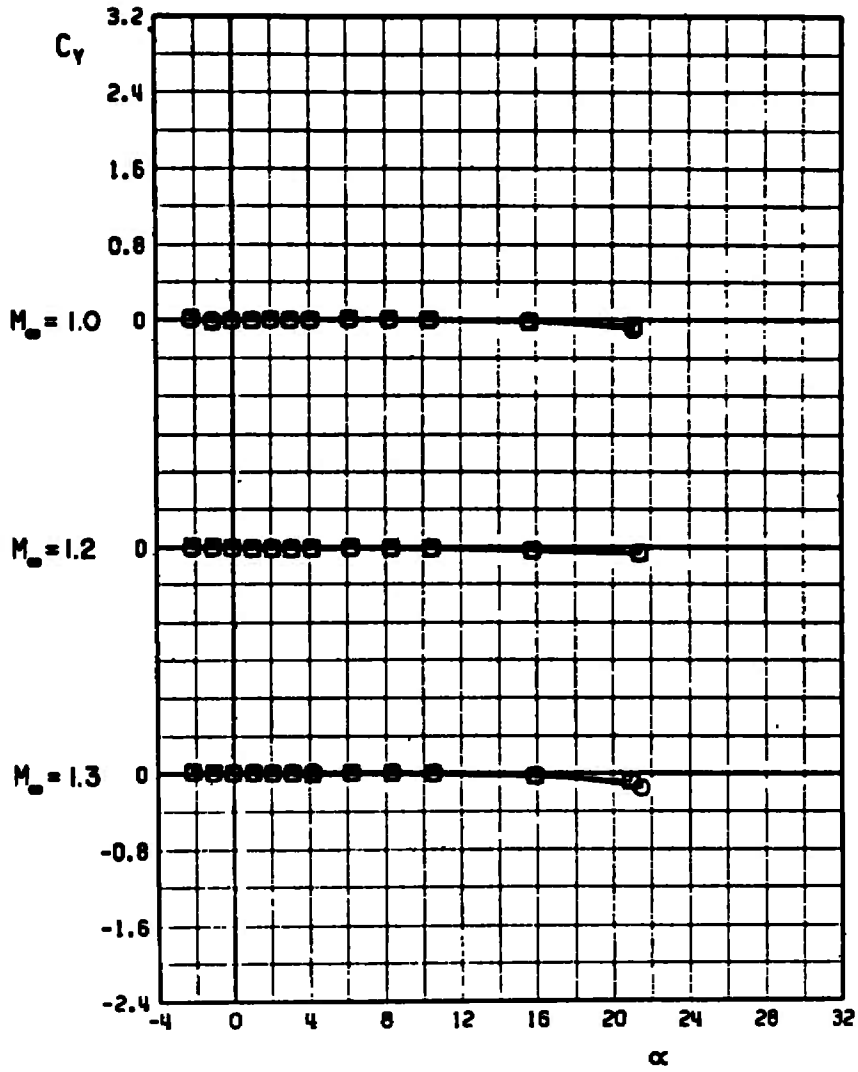
d.  $C_{A,b}$  versus  $\alpha$   
Fig. 6 Continued

	CONFIGURATION	b/D
○	N10 M4 R19	1.10
□	N10 M4 R20	1.10



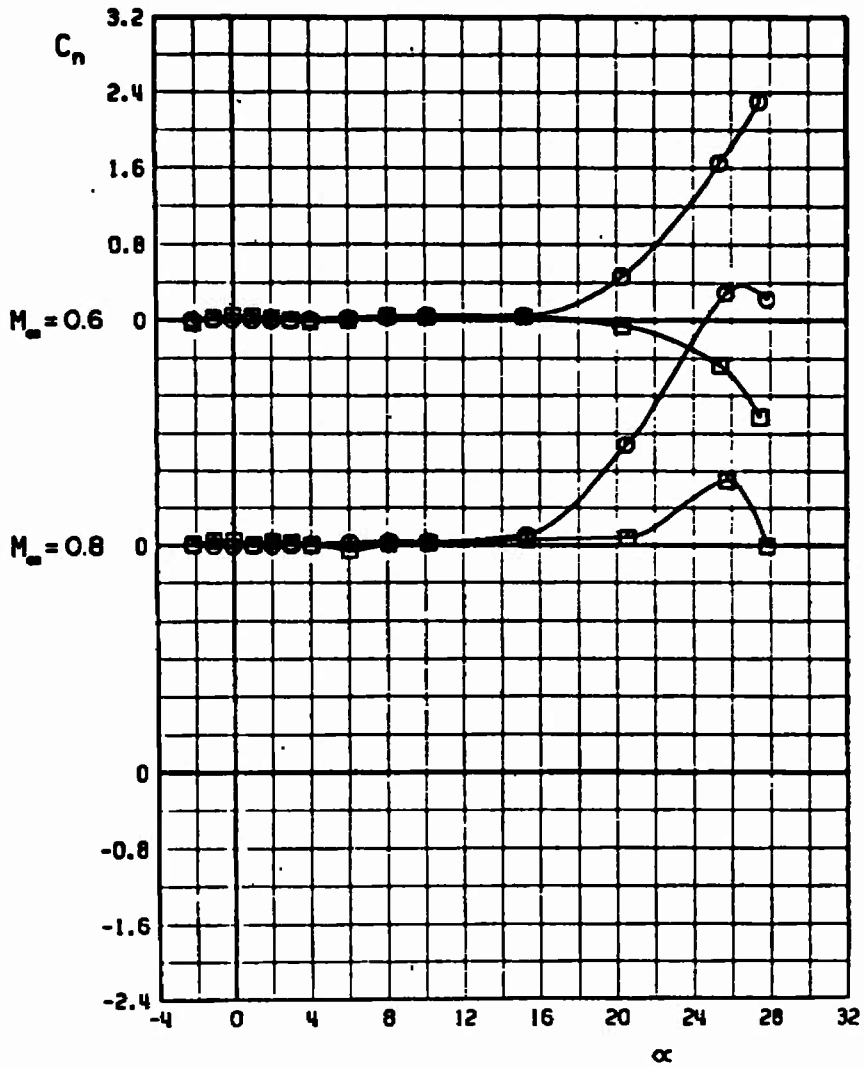
e.  $C_y$  versus  $\alpha$   
 Fig. 6 Continued

	CONFIGURATION	b/D
○	N10 M4 R19	1.10
□	N10 M4 R20	1.10



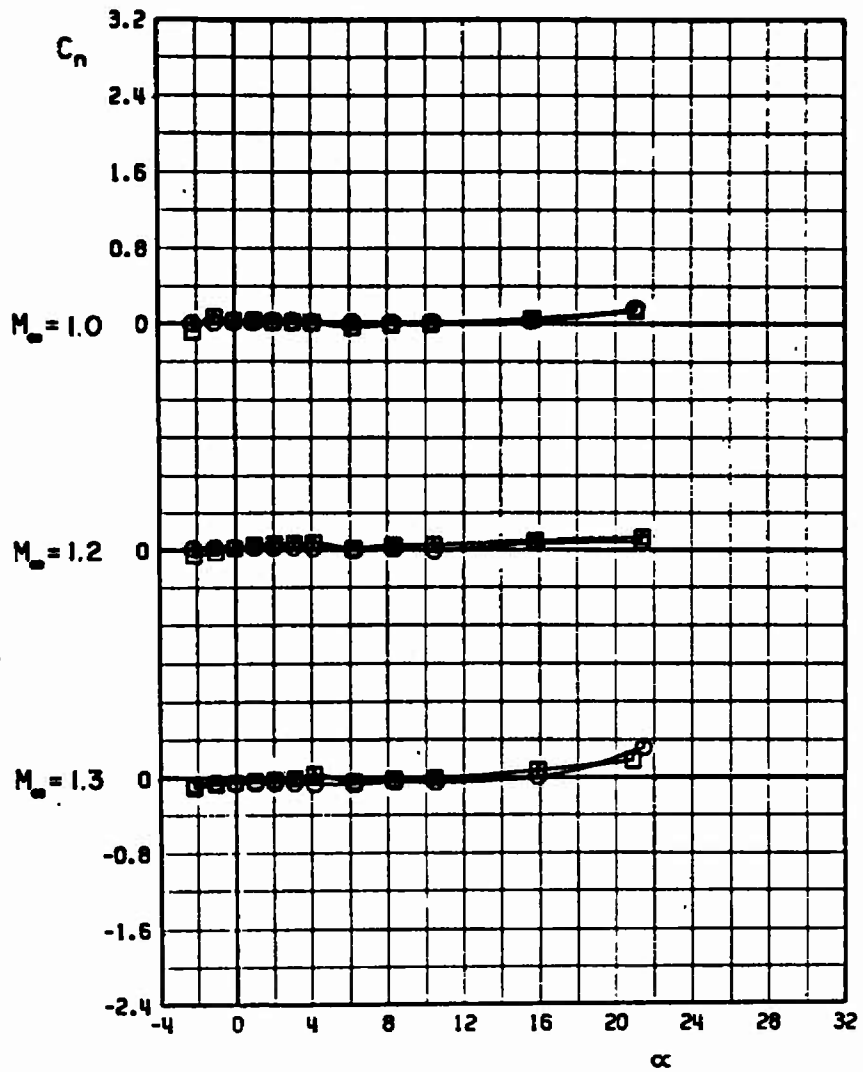
e. Concluded  
Fig. 6 Continued

	CONFIGURATION	b/D
○	N10 M4 R19	1.10
□	N10 M4 R20	1.10



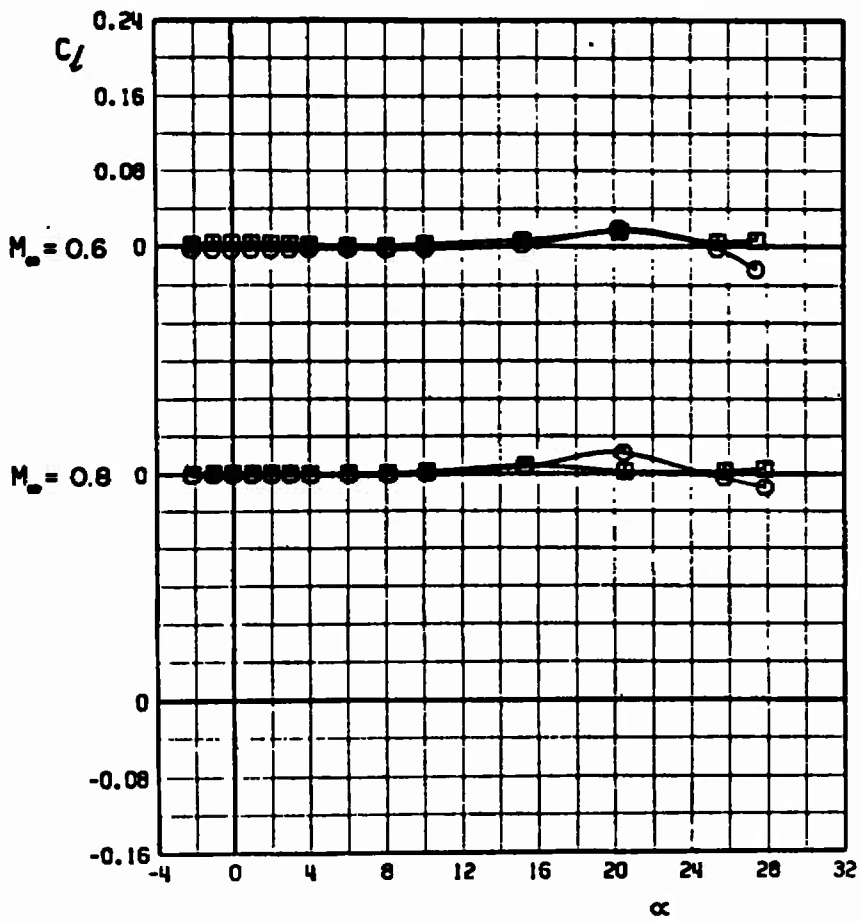
f.  $C_n$  versus  $\alpha$   
 Fig. 6 Continued

	CONFIGURATION	b/D
○	N10 M4 R19	1.10
□	N10 M4 R20	1.10



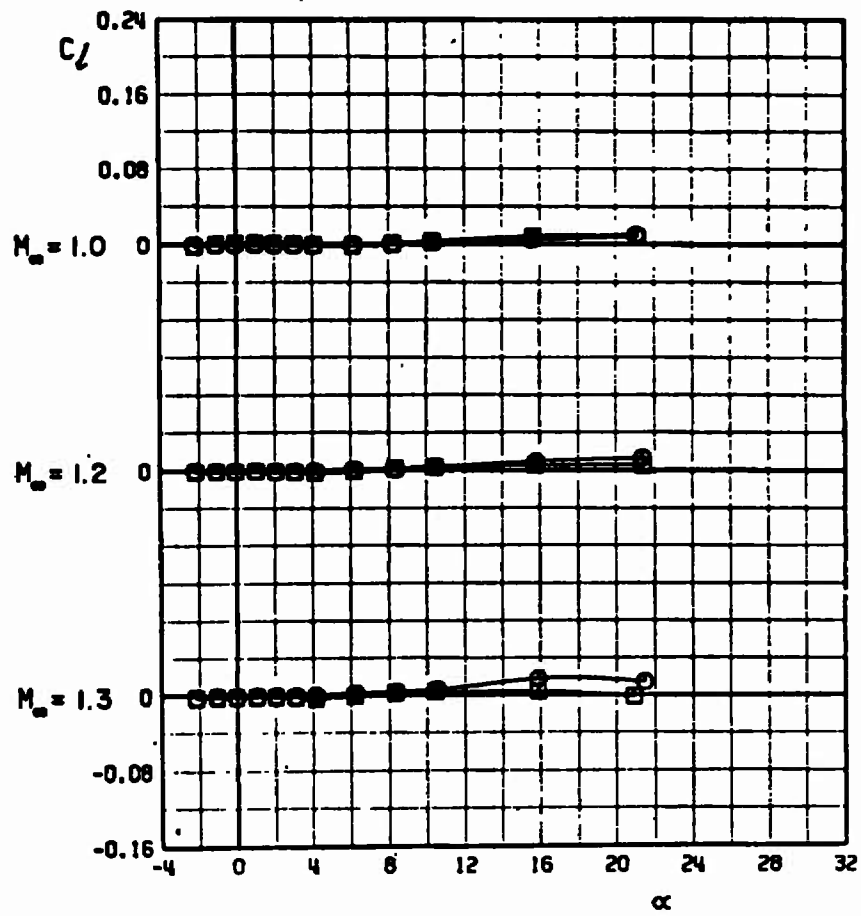
f. Concluded  
Fig. 6 Continued

CONFIGURATION b/D  
 ○ N10 M4 R19 1.10  
 □ N10 M4 R20 1.10



g.  $C_l$  versus  $\alpha$   
 Fig. 6 Continued

CONFIGURATION		b/D
○	N10 M4 A19	1.10
□	N10 M4 A20	1.10



g. Concluded  
Fig. 6 Concluded

	CONFIGURATION	b/D
○	N10 M4 A21	1.00
□	N10 M4 A21	1.10
△	N10 M4 A22	1.00

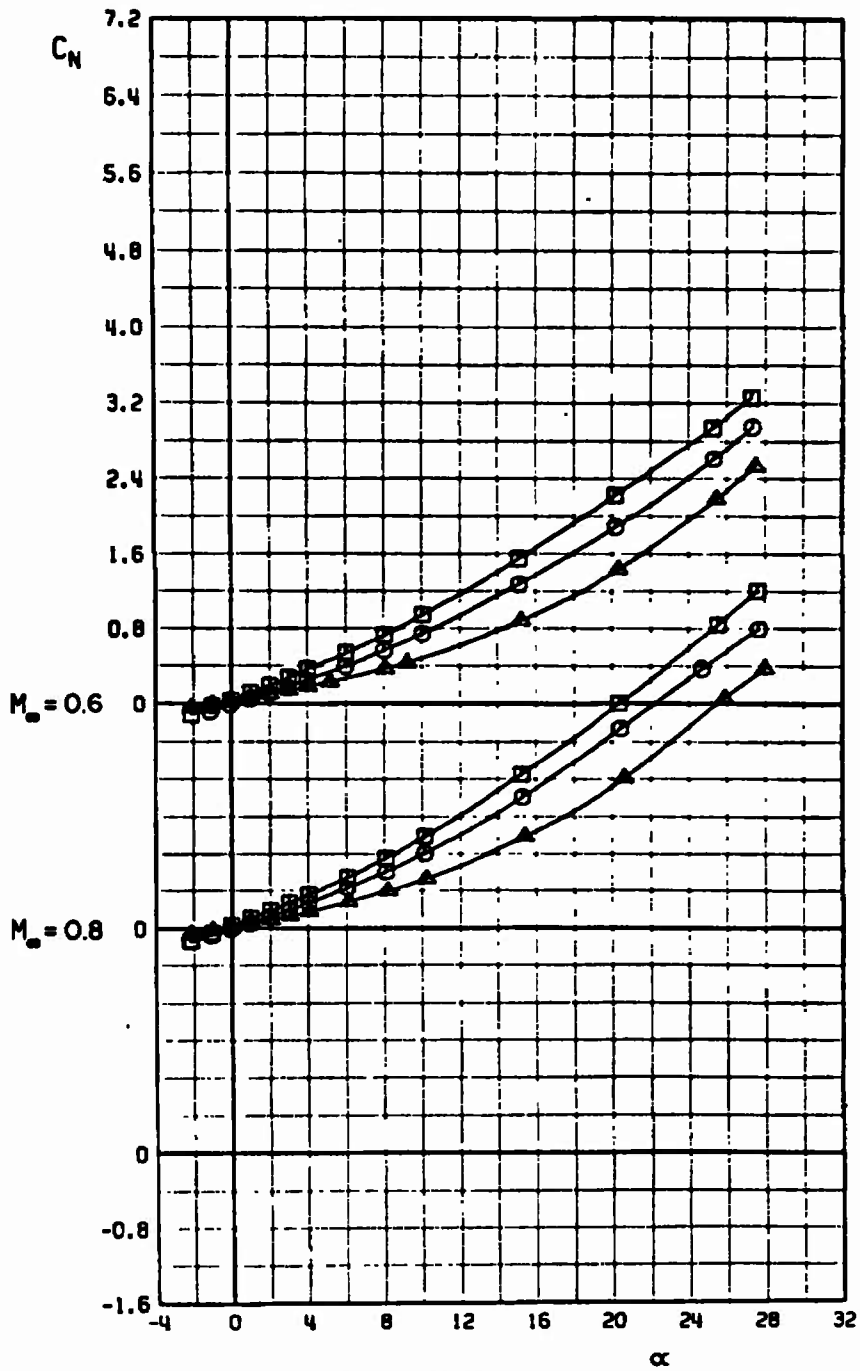
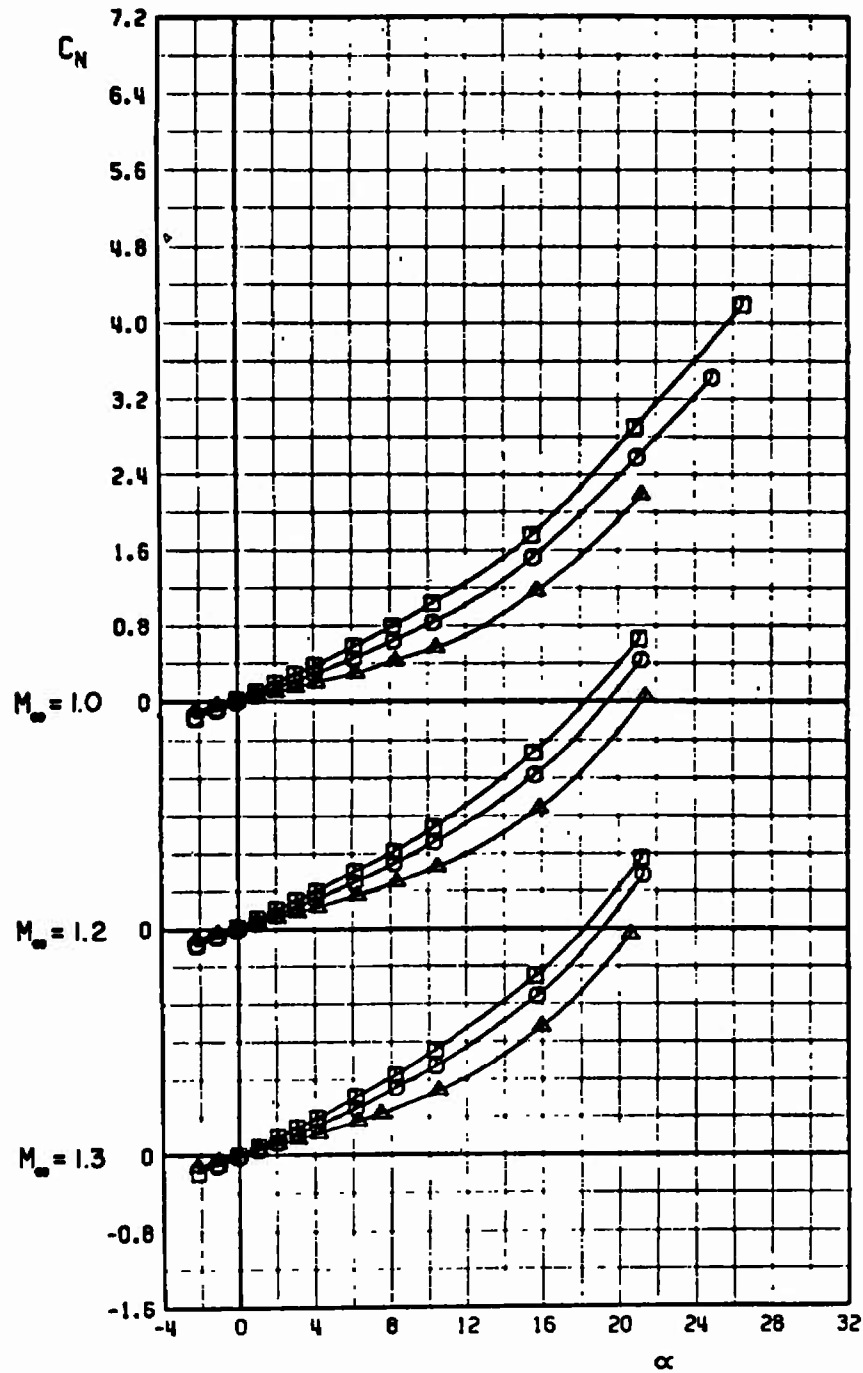


Fig. 7 Aerodynamic Coefficients of Configurations N10M4A21, b/D = 1.00 and 1.10 and Configuration N10M4A22, b/D = 1.00



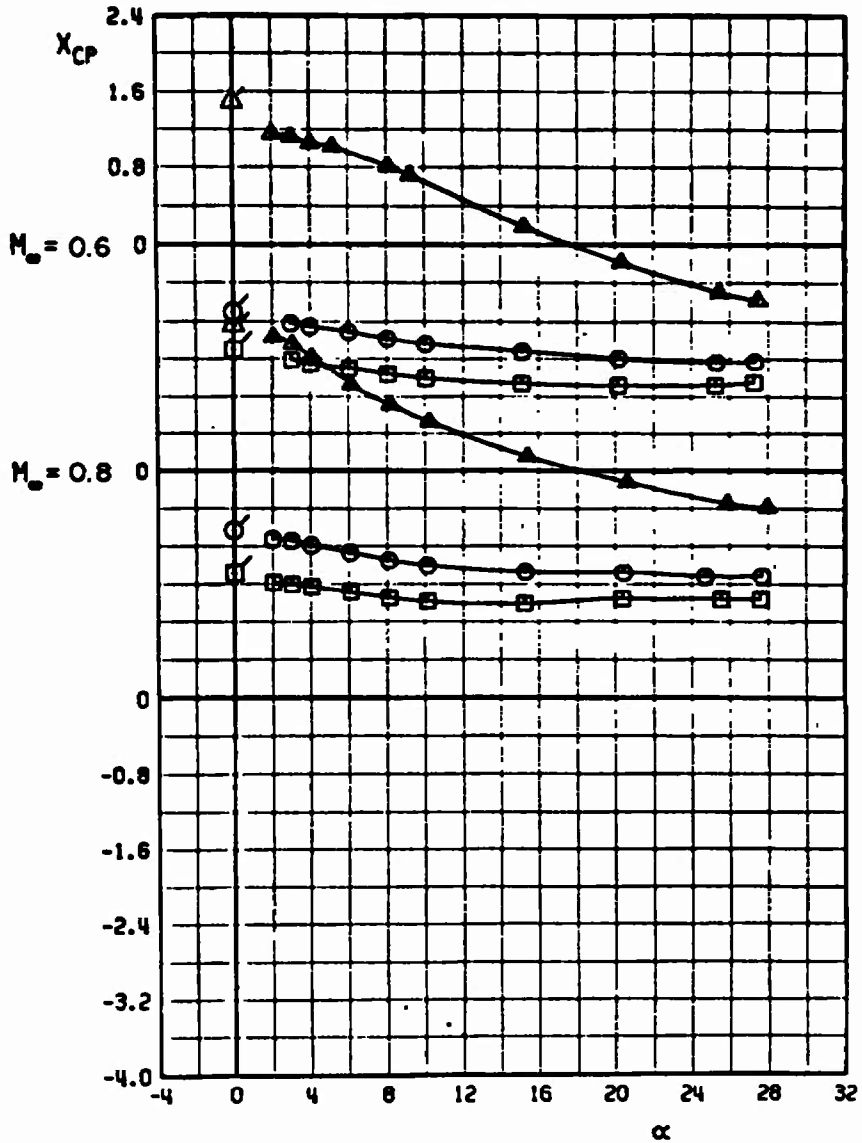
	CONFIGURATION	b/D.
○	N10 M4 A21	1.00
□	N10 M4 A21	1.10
△	N10 M4 A22	1.00



a. Concluded  
Fig. 7 Continued

	CONFIGURATION	b/D
○	N10 M4 R21	1.00
□	N10 M4 R21	1.10
△	N10 M4 R22	1.00

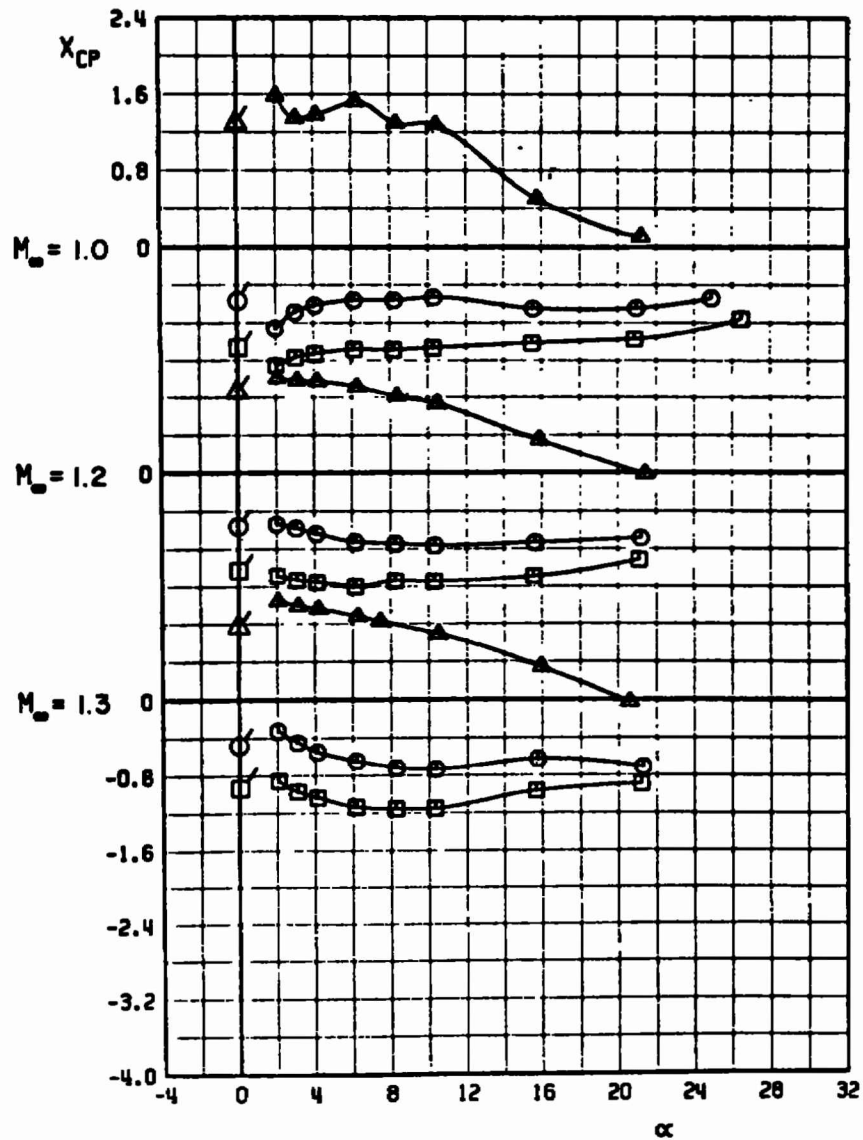
FLAGGED SYMBOLS DENOTE NEUTRAL-POINT LOCATIONS



b.  $X_{CP}$  versus  $\alpha$   
Fig. 7 Continued

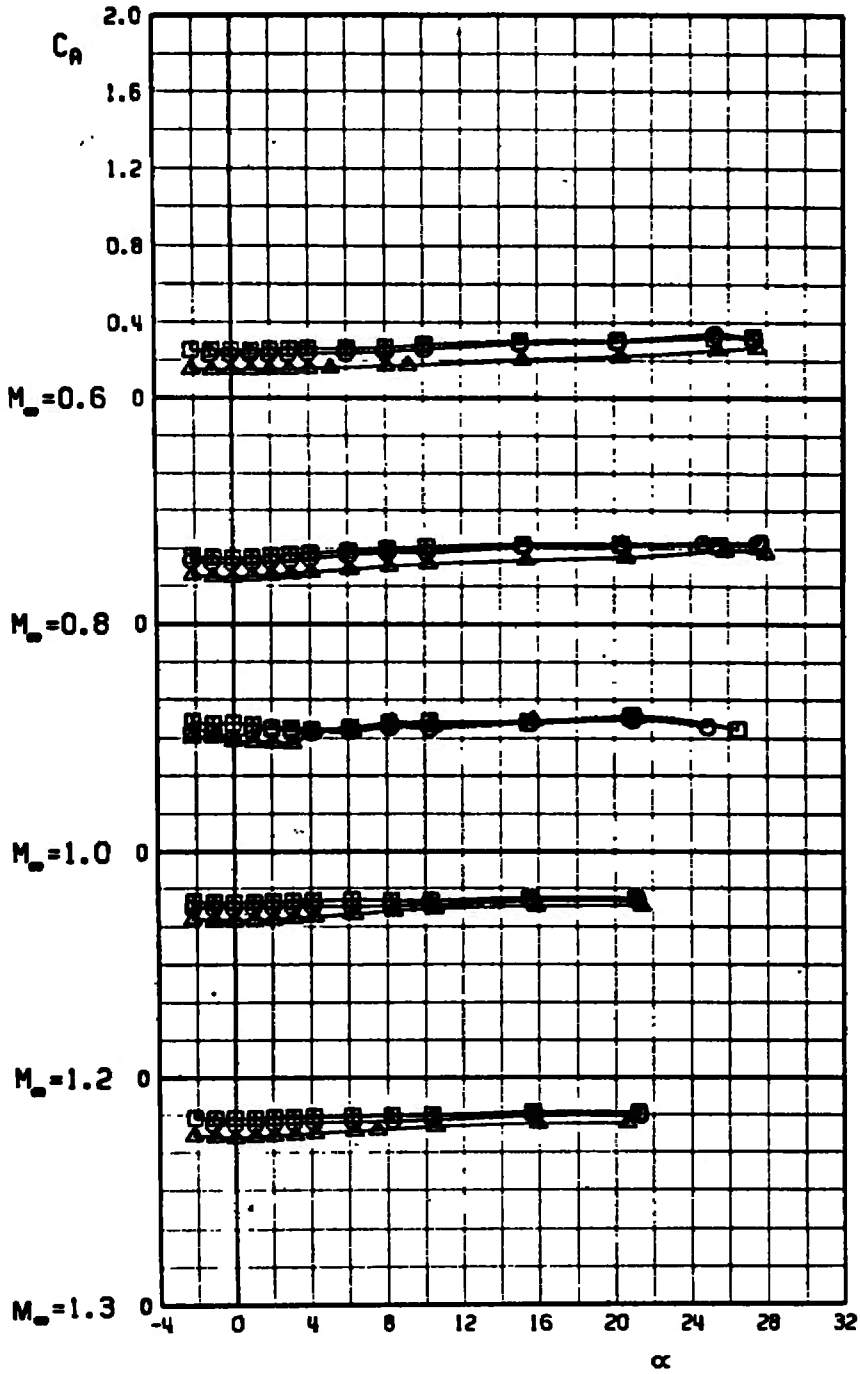
	CONFIGURATION	b/D
○	N10 M4 R21	1.00
□	N10 M4 R21	1.10
△	N10 M4 R22	1.00

FLAGGED SYMBOLS DENOTE NEUTRAL-POINT LOCATIONS



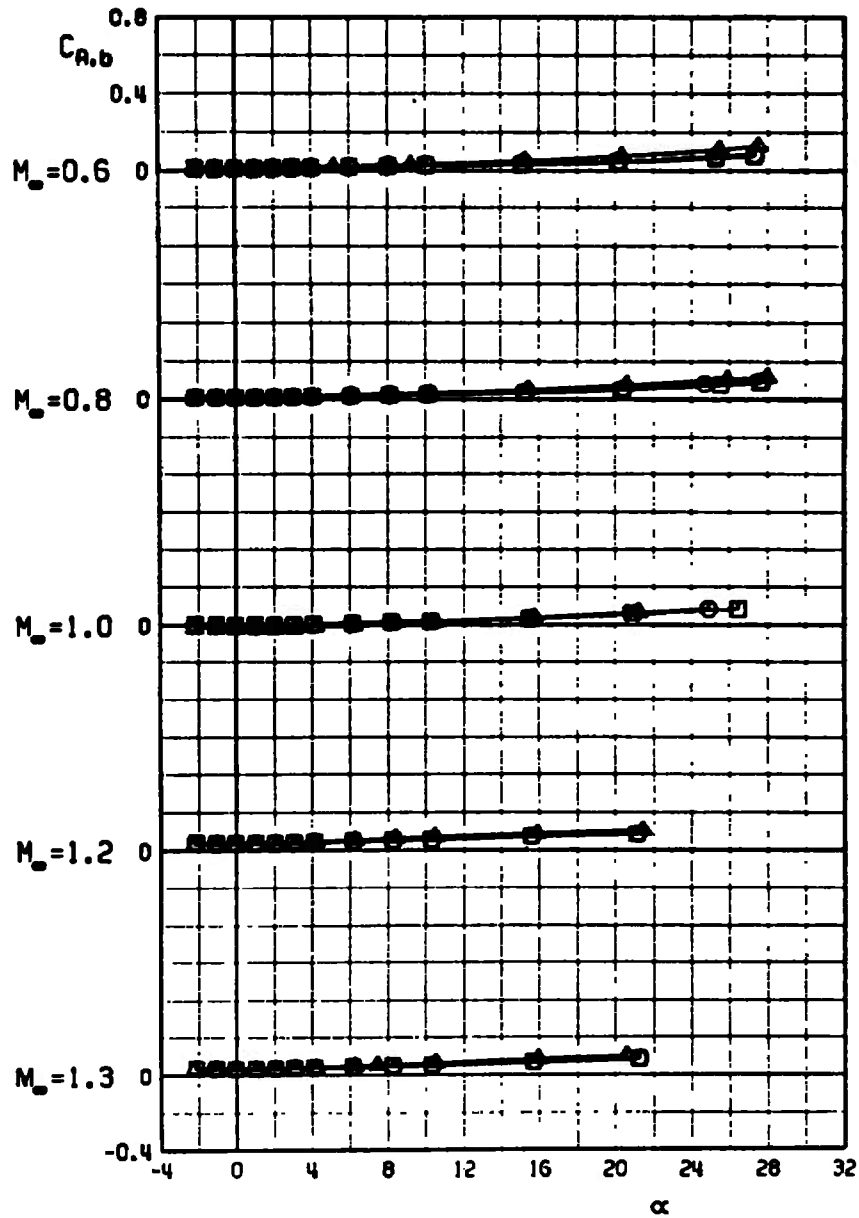
b. Concluded  
Fig. 7 Continued

	CONFIGURATION	b/D
○	N10 M4 R21	1.00
□	N10 M4 R21	1.10
△	N10 M4 R22	1.00



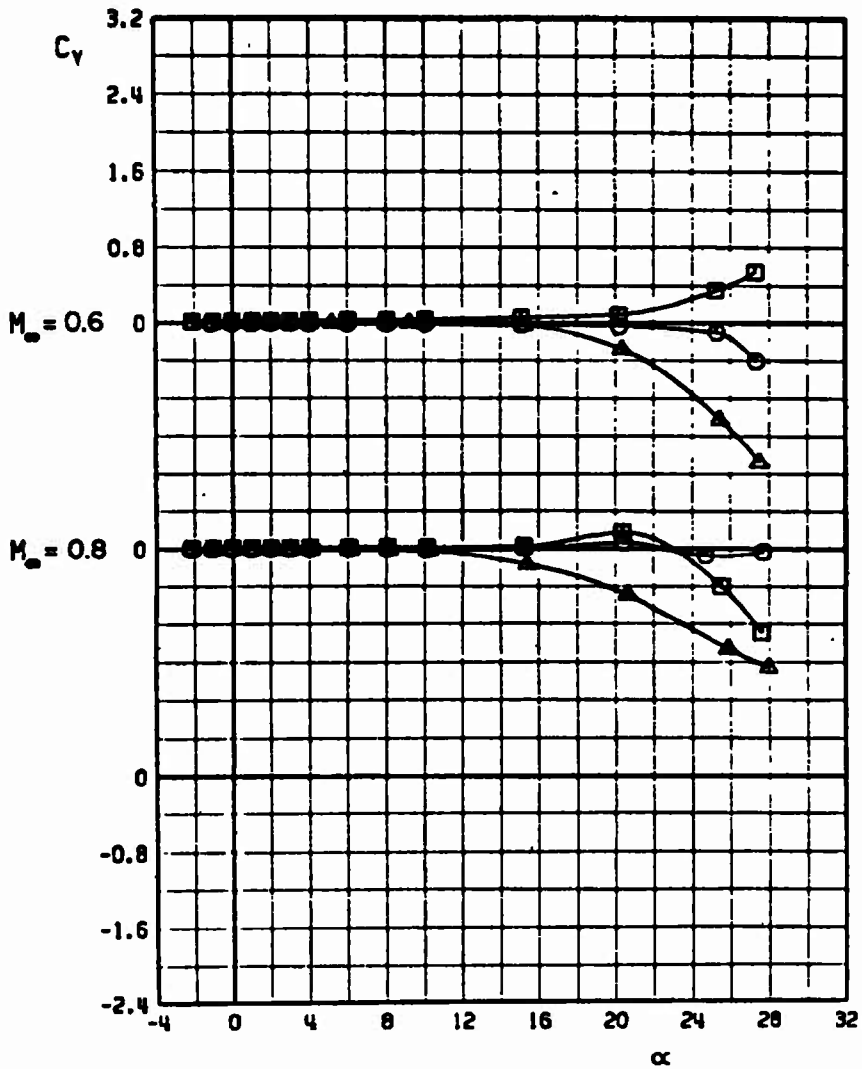
c.  $C_A$  versus  $\alpha$   
 Fig. 7 Continued

	CONFIGURATION	b/D
○	N10 M4 R21	1.00
□	N10 M4 R21	1.10
△	N10 M4 R22	1.00



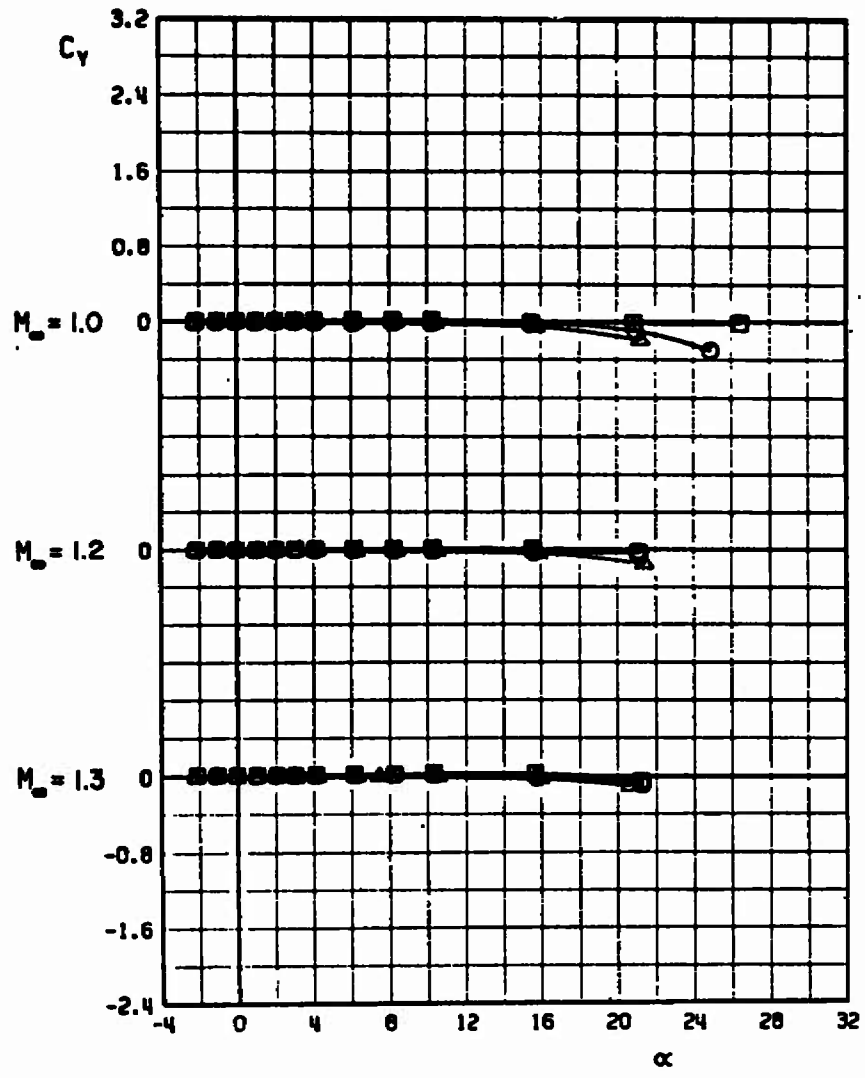
d.  $C_{A,b}$  versus  $\alpha$   
 Fig. 7 Continued

	CONFIGURATION	b/D
○	N10 M4 R21	1.00
□	N10 M4 R21	1.10
△	N10 M4 R22	1.00



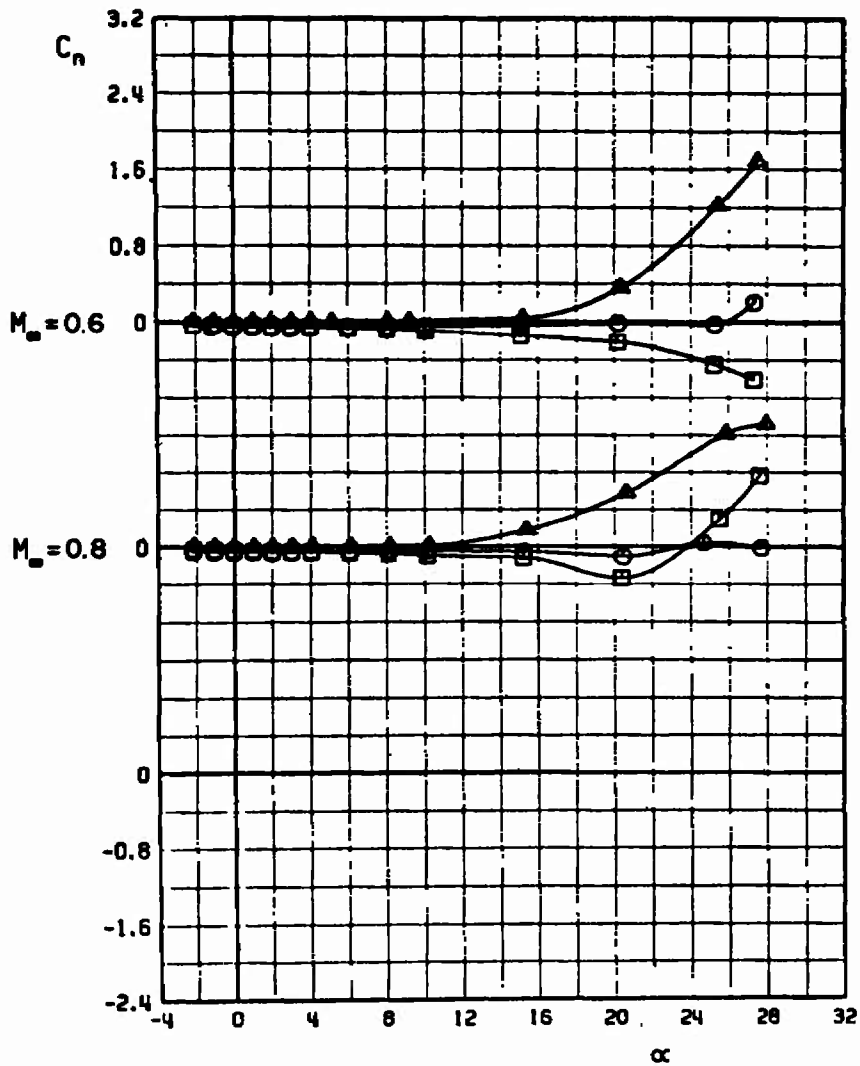
e.  $C_y$  versus  $\alpha$   
Fig. 7 Continued

	CONFIGURATION	b/D
○	N10 M4 R21	1.00
□	N10 M4 R21	1.10
△	N10 M4 R22	1.00



e. Concluded  
Fig. 7 Continued

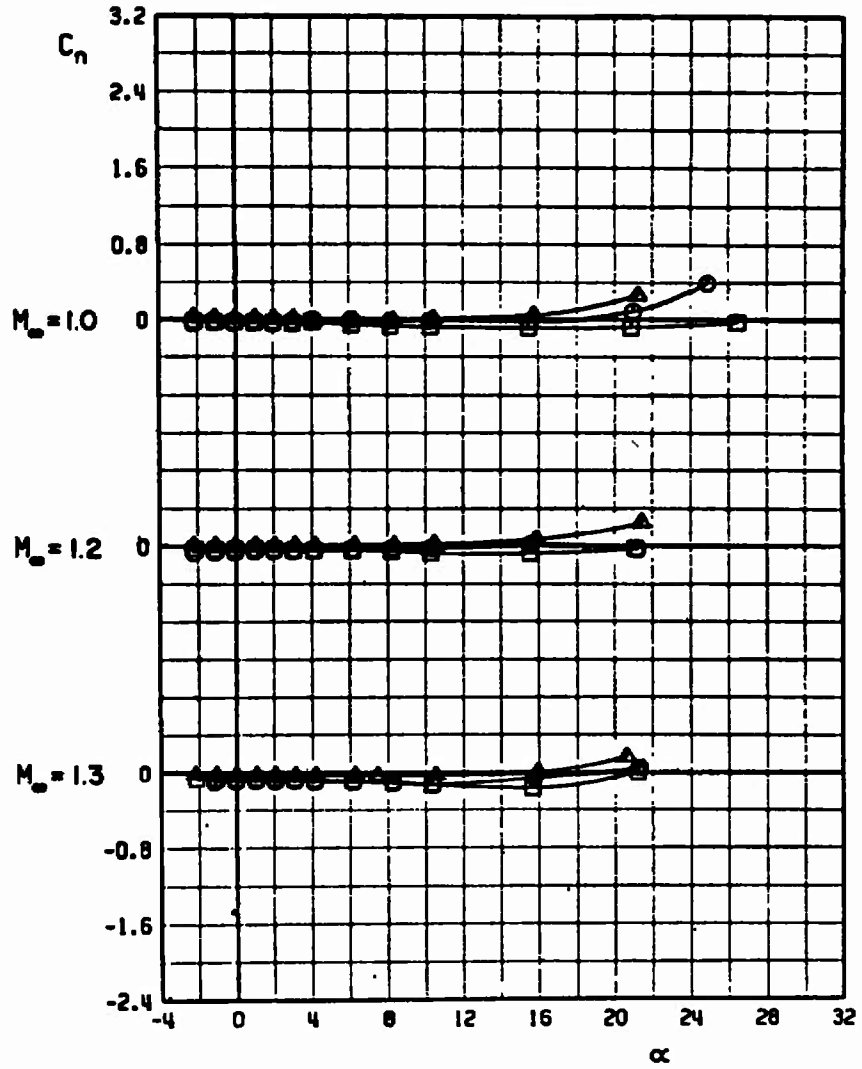
	CONFIGURATION	b/D
○	N10 M4 R21	1.00
□	N10 M4 R21	1.10
△	N10 M4 R22	1.00



f.  $C_n$  versus  $\alpha$   
Fig. 7 Continued

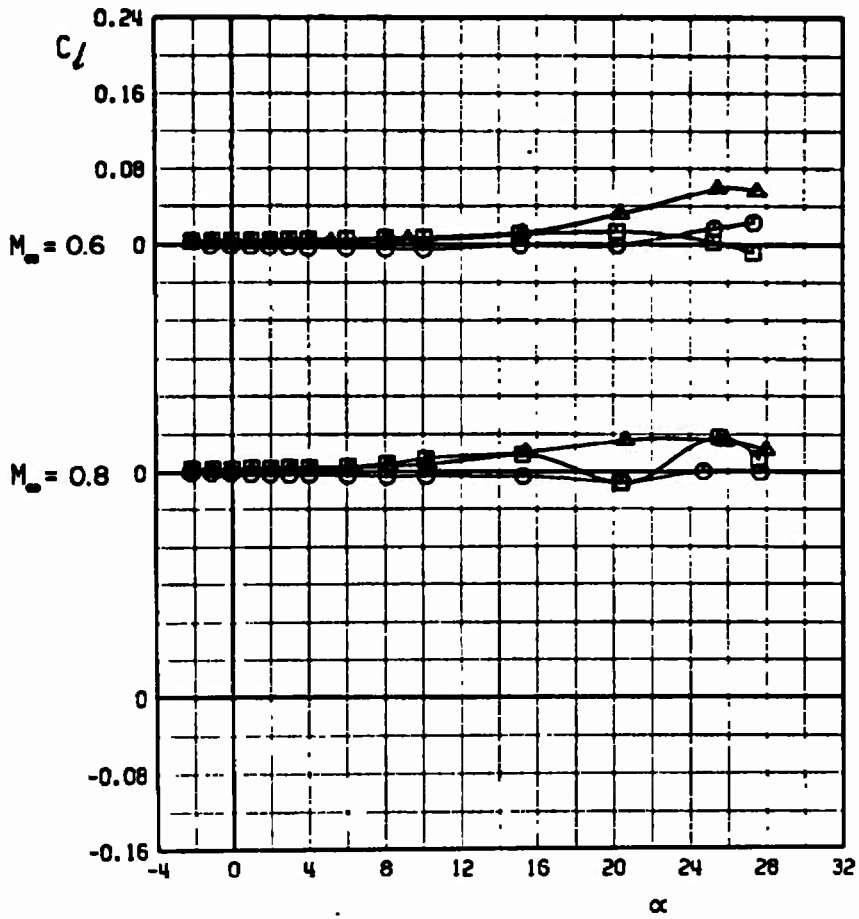


	CONFIGURATION	b/D
○	N10 M4 A21	1.00
□	N10 M4 A21	1.10
△	N10 M4 A22	1.00



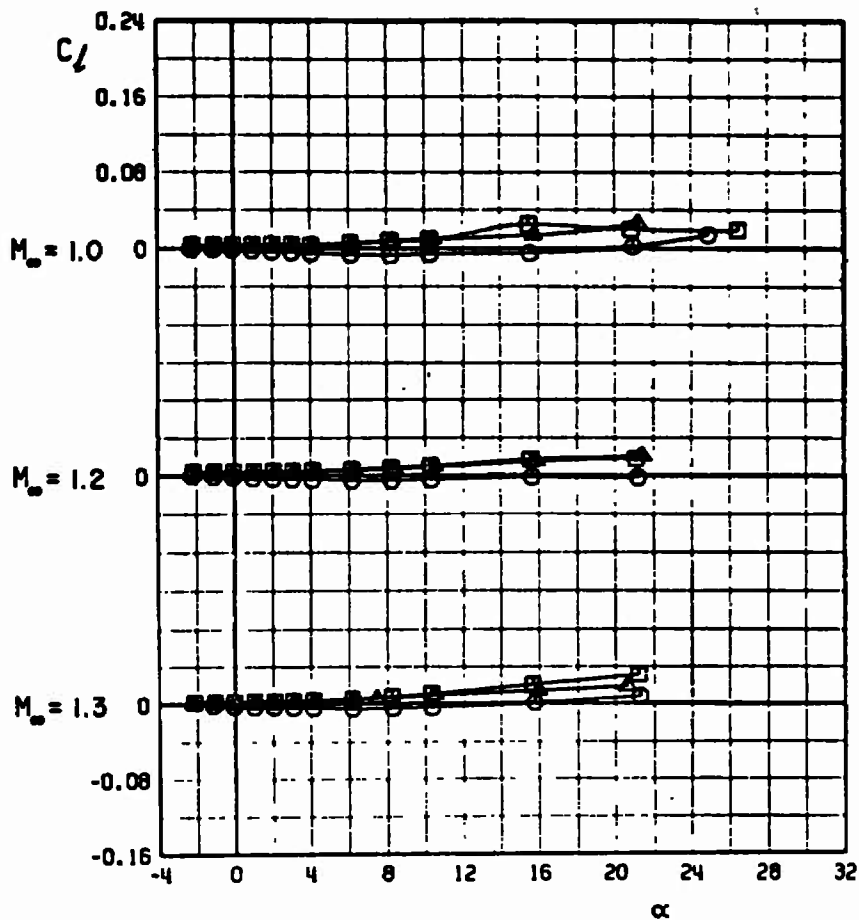
f. Concluded  
Fig. 7 Continued

CONFIGURATION		b/D
○	N10 M4 R21	1.00
□	N10 M4 R21	1.10
△	N10 M4 R22	1.00



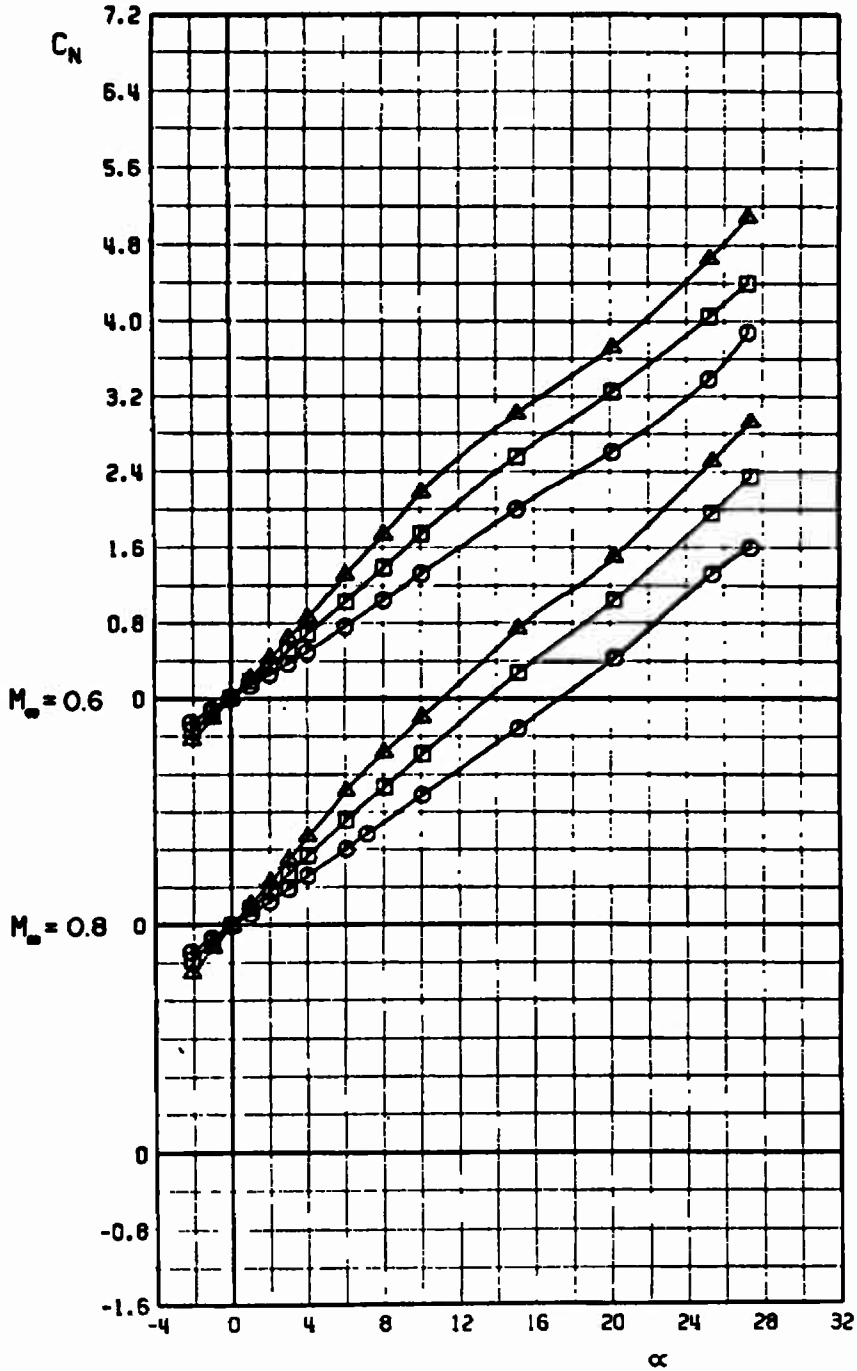
g.  $C_q$  versus  $\alpha$   
 Fig. 7 Continued

	CONFIGURATION	b/D
○	N10 M4 R21	1.00
□	N10 M4 R21	1.10
△	N10 M4 R22	1.00



g. Concluded  
Fig. 7 Concluded

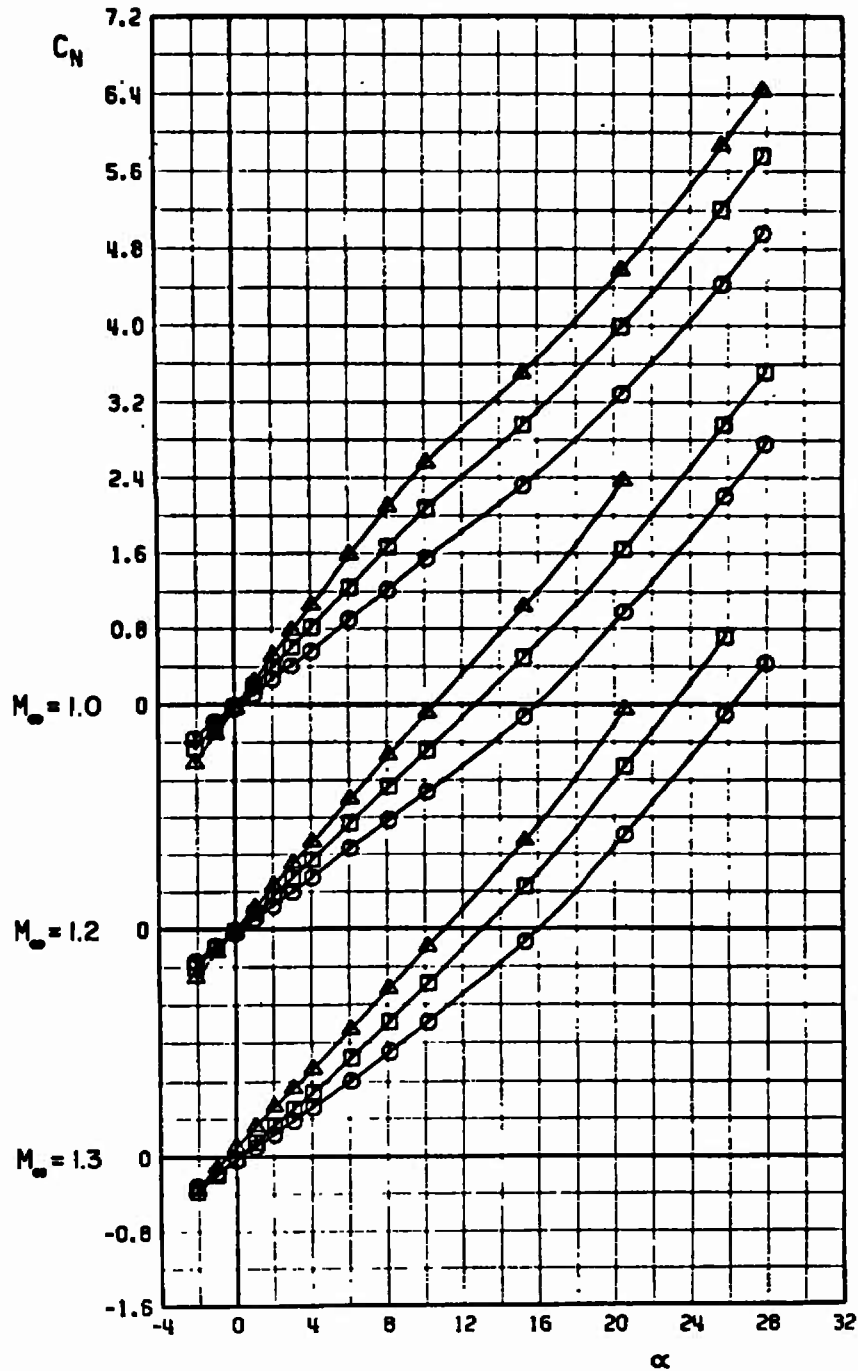
CONFIGURATION	b/D
○	N10 M4 A18 2.30
□	N10 M4 A18 2.88
△	N10 M4 A18 3.46



a.  $C_N$  versus  $\alpha$

Fig. 8 Aerodynamic Coefficients of Configurations N10M4A18,  $b/D = 2.30$ , 2.88 and 3.46

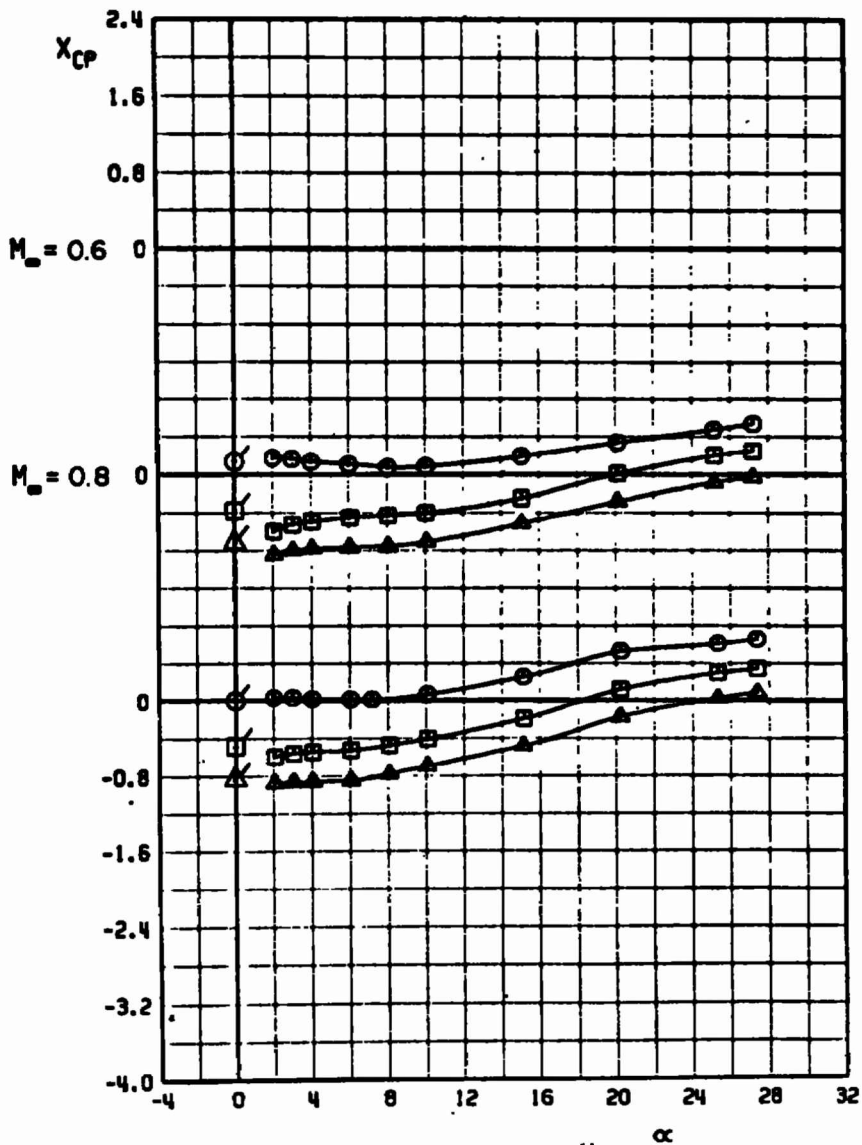
	CONFIGURATION	b/D
○	N10 M4 R18	2.30
□	N10 M4 R18	2.88
△	N10 M4 R18	3.46



a. Concluded  
Fig. 8 Continued

	CONFIGURATION	b/D
○	N10 M4 A18	2.30
□	N10 M4 A18	2.88
△	N10 M4 A18	3.46

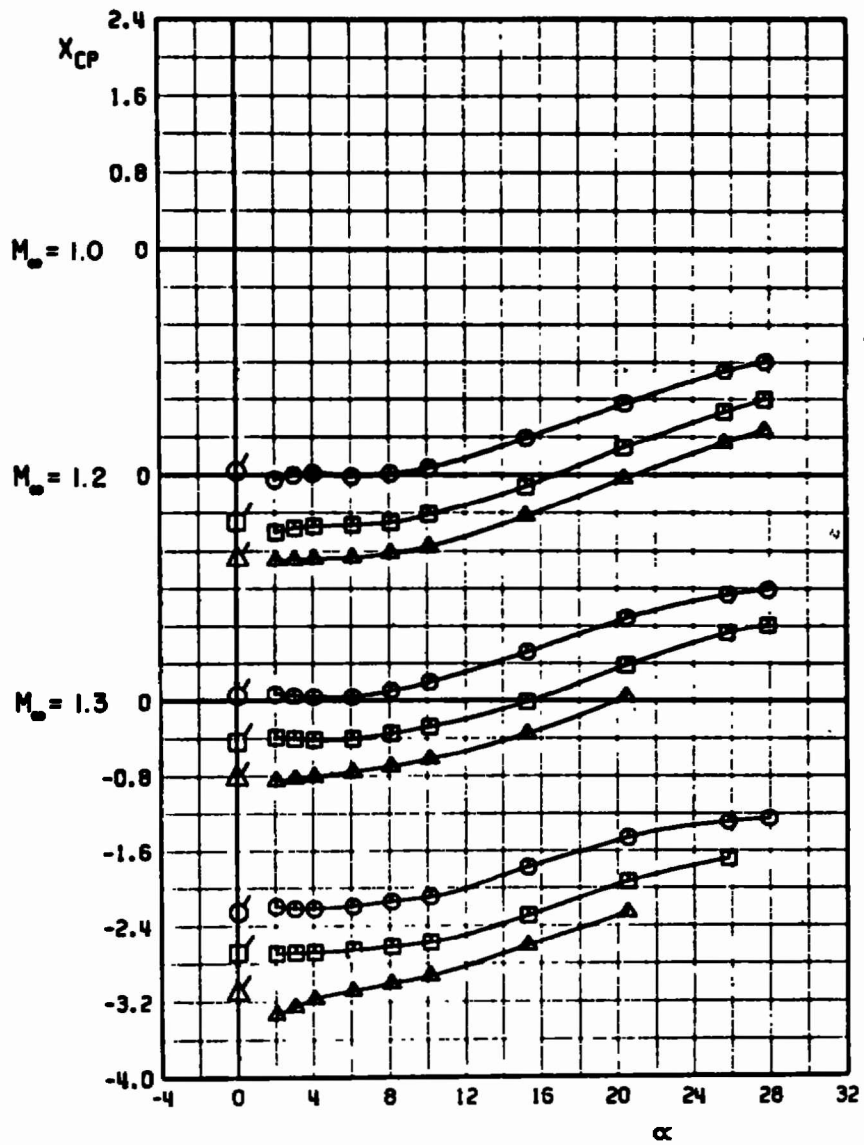
FLAGGED SYMBOLS DENOTE NEUTRAL-POINT LOCATIONS



b.  $X_{cp}$  versus  $\alpha$   
 Fig. 8 Continued

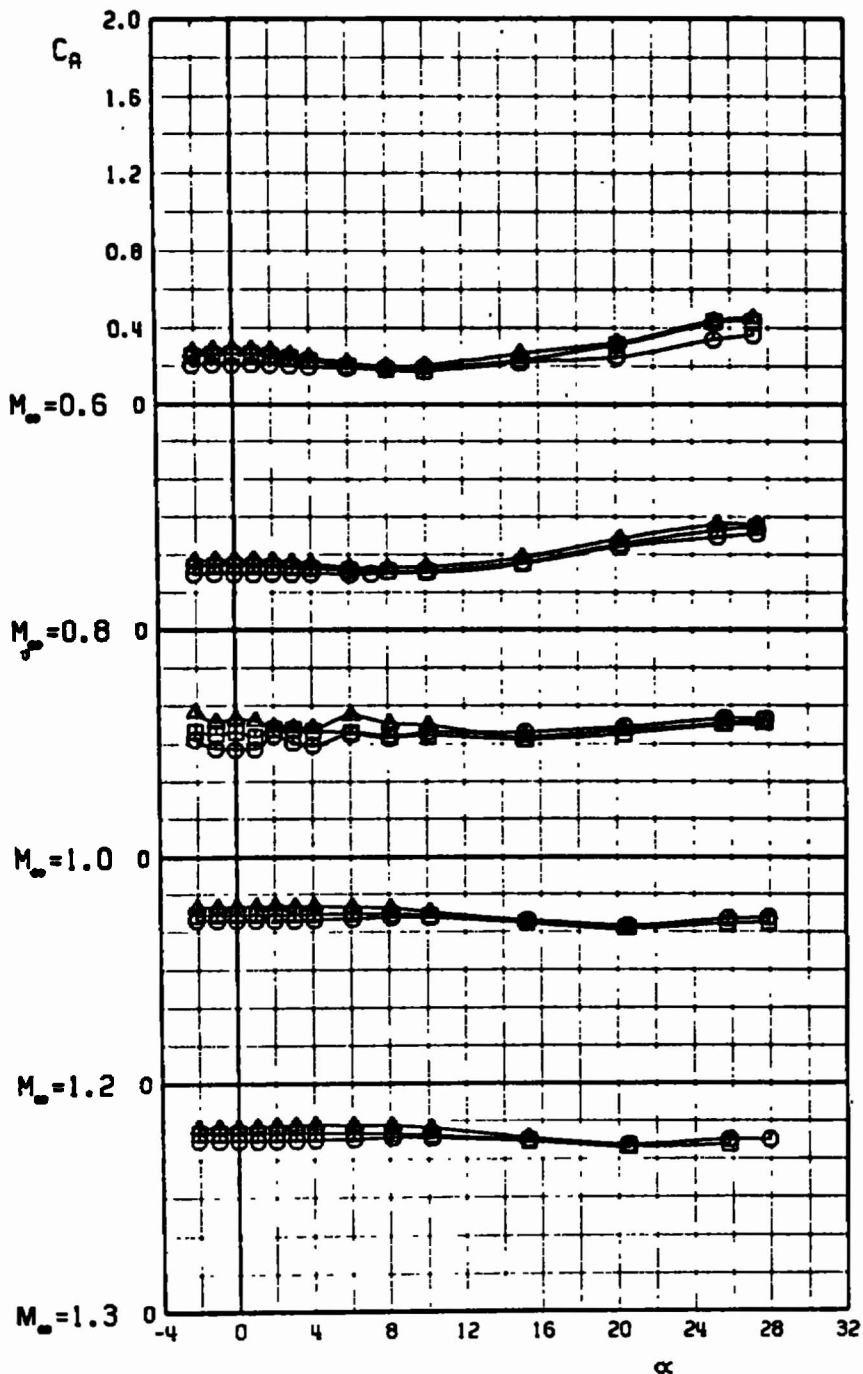
	CONFIGURATION	b/D
○	N10 M4 A18	2.30
□	N10 M4 A18	2.88
△	N10 M4 A18	3.46

FLAGGED SYMBOLS DENOTE NEUTRAL-POINT LOCATIONS



b. Concluded  
Fig. 8 Continued

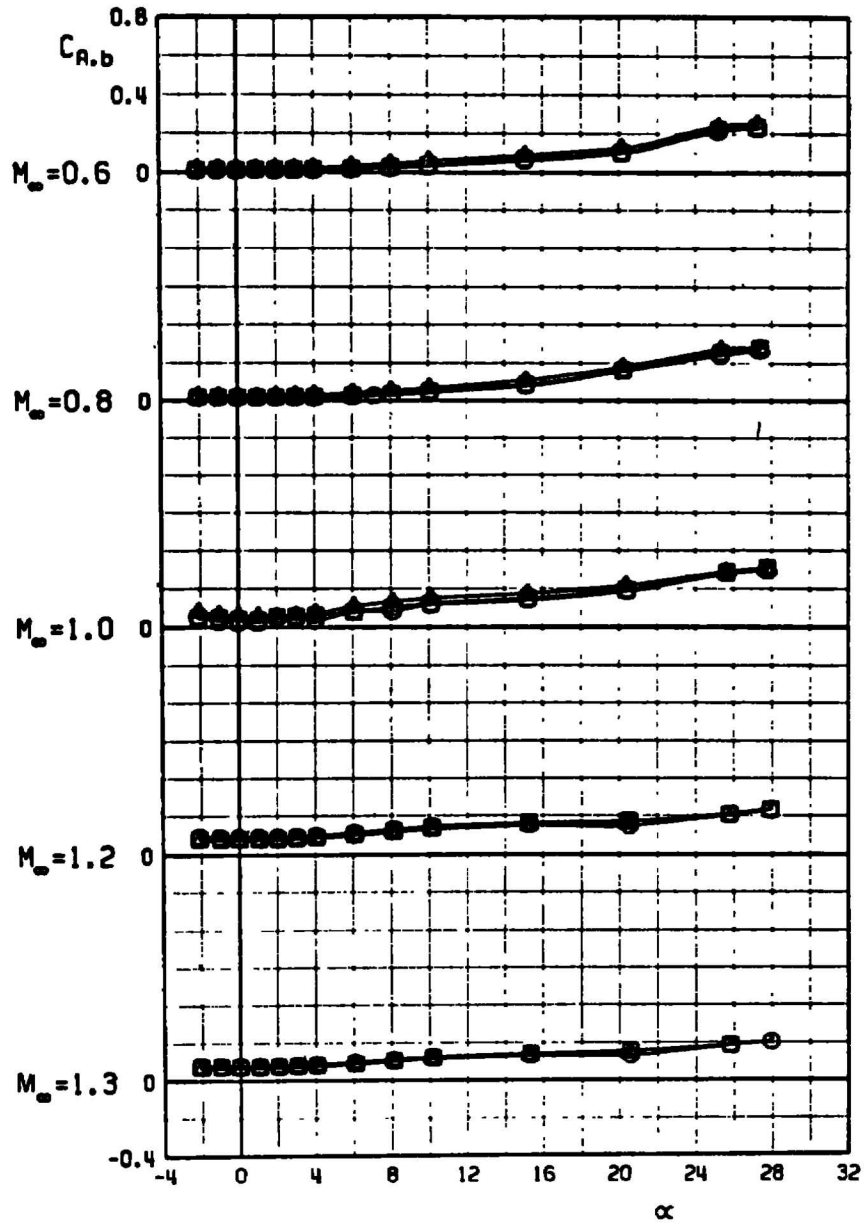
	CONFIGURATION	b/D
○	N10 M4 R18	2.30
□	N10 M4 R18	2.88
△	N10 M4 R18	3.46



c.  $C_A$  versus  $\alpha$   
Fig. 8 Continued

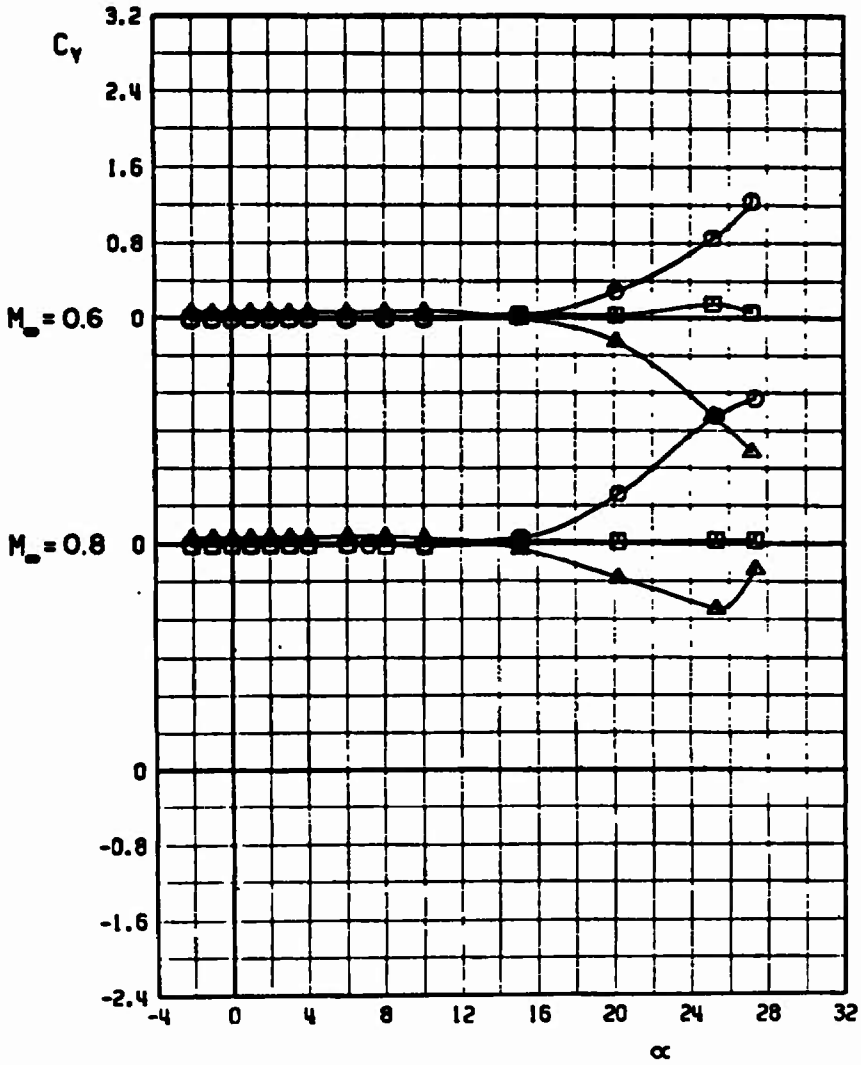


	CONFIGURATION	b/D
○	N10 M4 R18	2.30
□	N10 M4 R18	2.88
△	N10 M4 R18	3.46



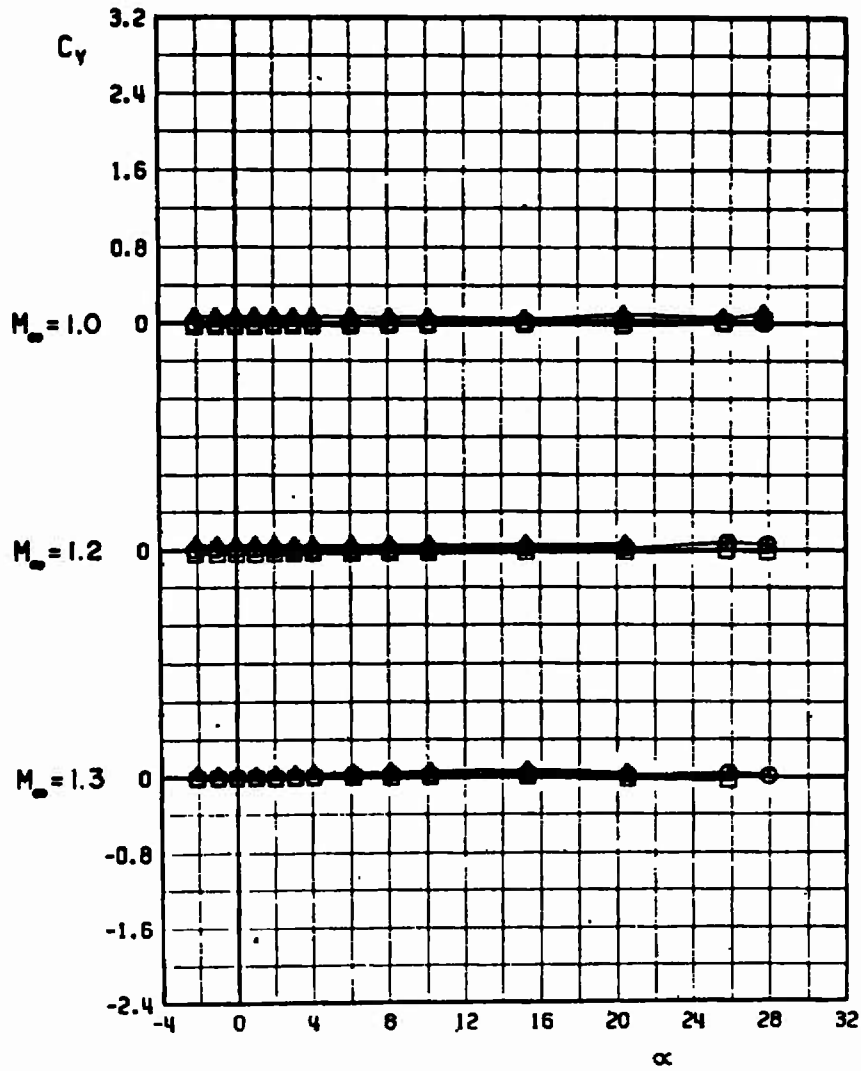
d.  $C_{A,b}$  versus  $\alpha$   
Fig. 8 Continued

	CONFIGURATION	b/D
○	N10 M4 R18	2.30
□	N10 M4 R18	2.88
△	N10 M4 R18	3.46



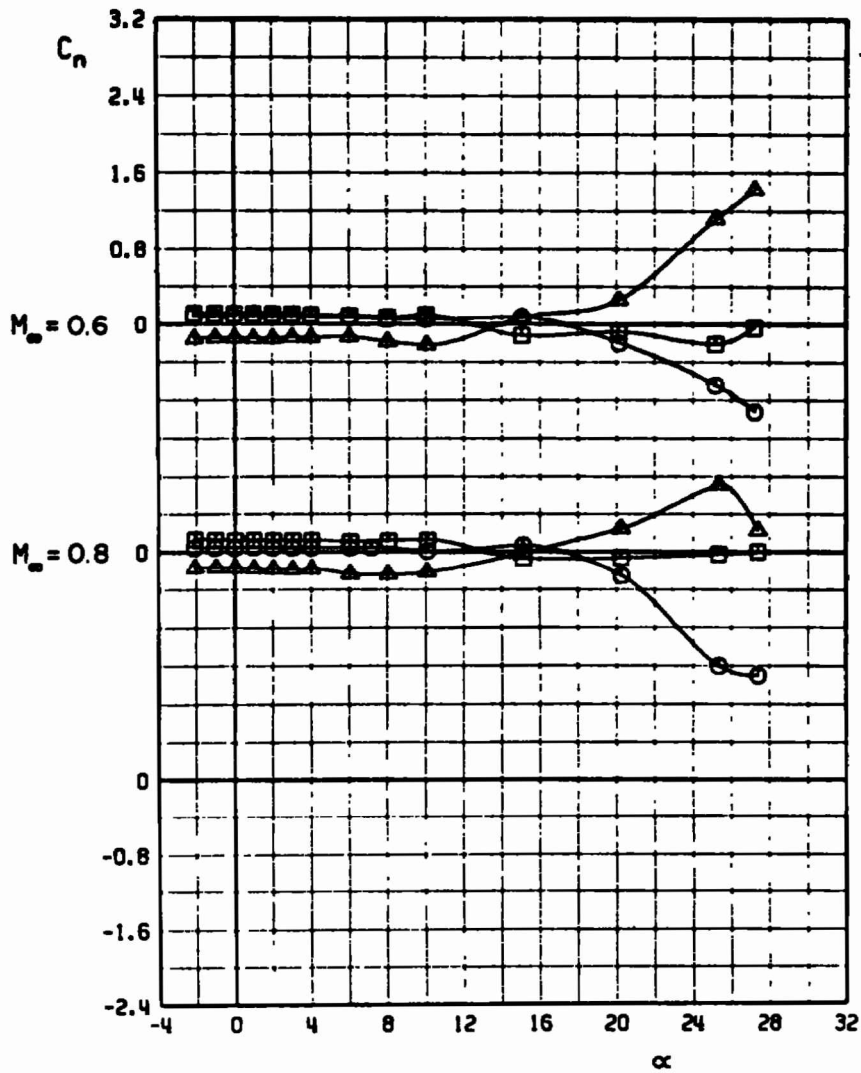
e.  $C_Y$  versus  $\alpha$   
Fig. 8 Continued

	CONFIGURATION	b/D
○	N10 M4 R18	2.30
□	N10 M4 R18	2.88
△	N10 M4 R18	3.46



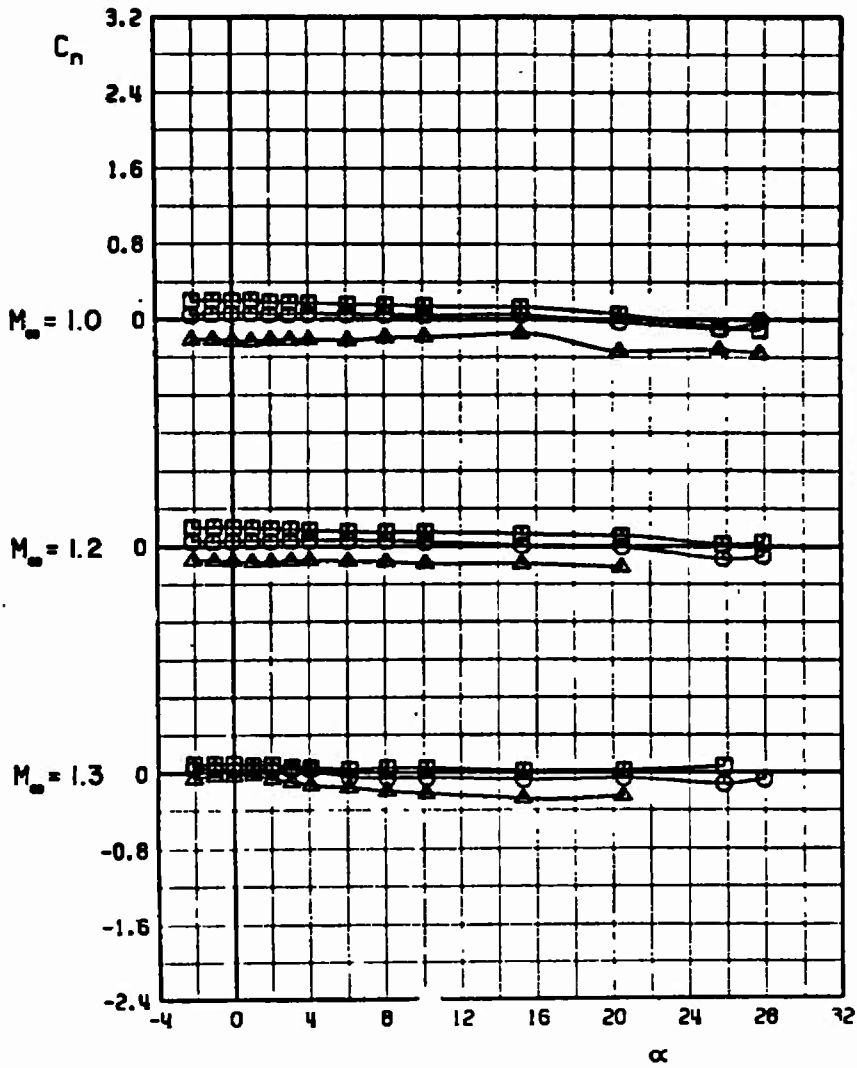
e. Concluded  
Fig. 8 Continued

	CONFIGURATION	b/D
○	N10 M4 A18	2.30
□	N10 M4 A18	2.88
△	N10 M4 A18	3.46



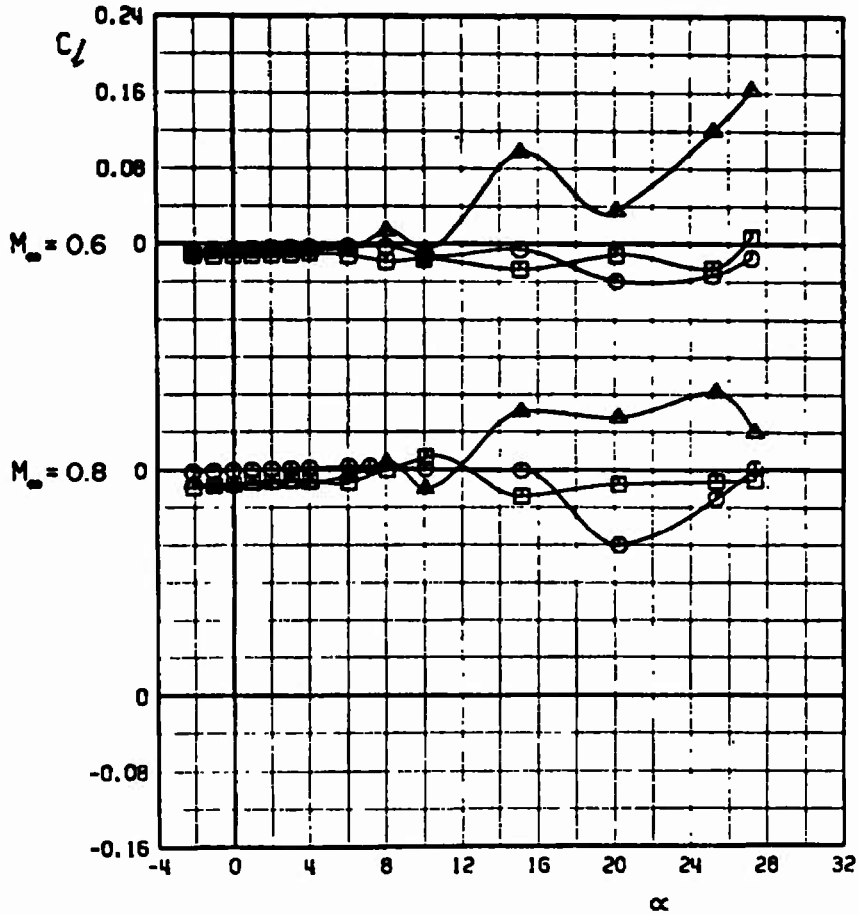
f.  $C_n$  versus  $\alpha$   
 Fig. 8 Continued

	CONFIGURATION	b/D
○	N10 M4 A18	2.30
□	N10 M4 A18	2.88
△	N10 M4 A18	3.46



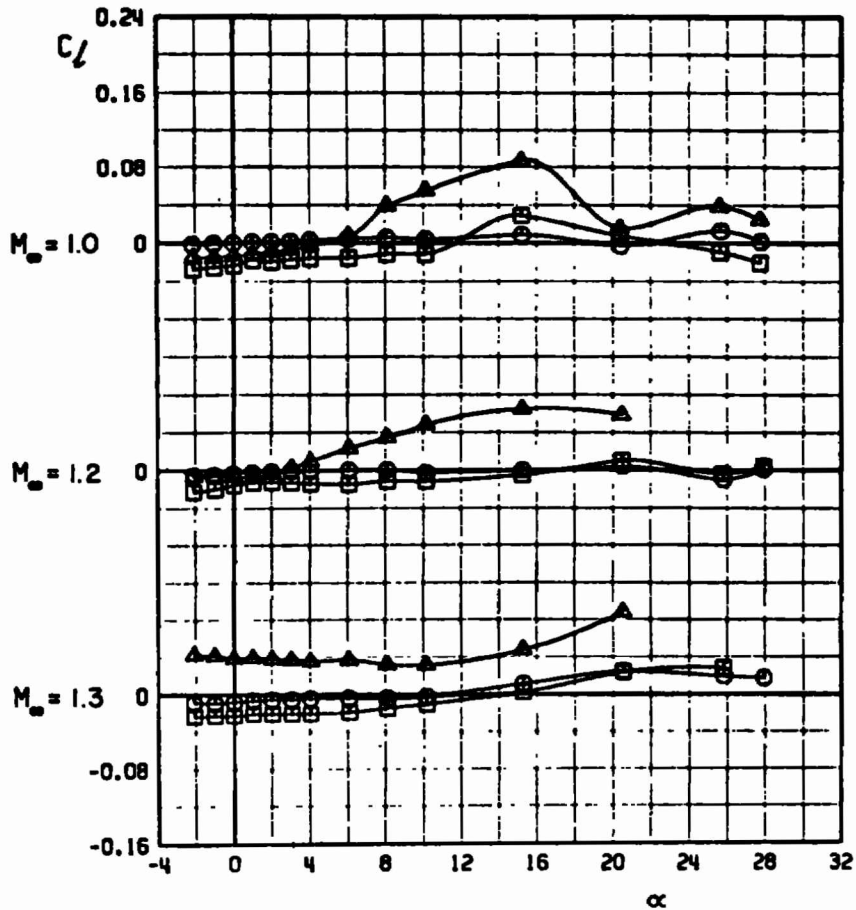
f. Concluded  
Fig. 8 Continued

	CONFIGURATION	b/D
○	N10 M4 A18	2.30
□	N10 M4 A18	2.88
△	N10 M4 A18	3.46



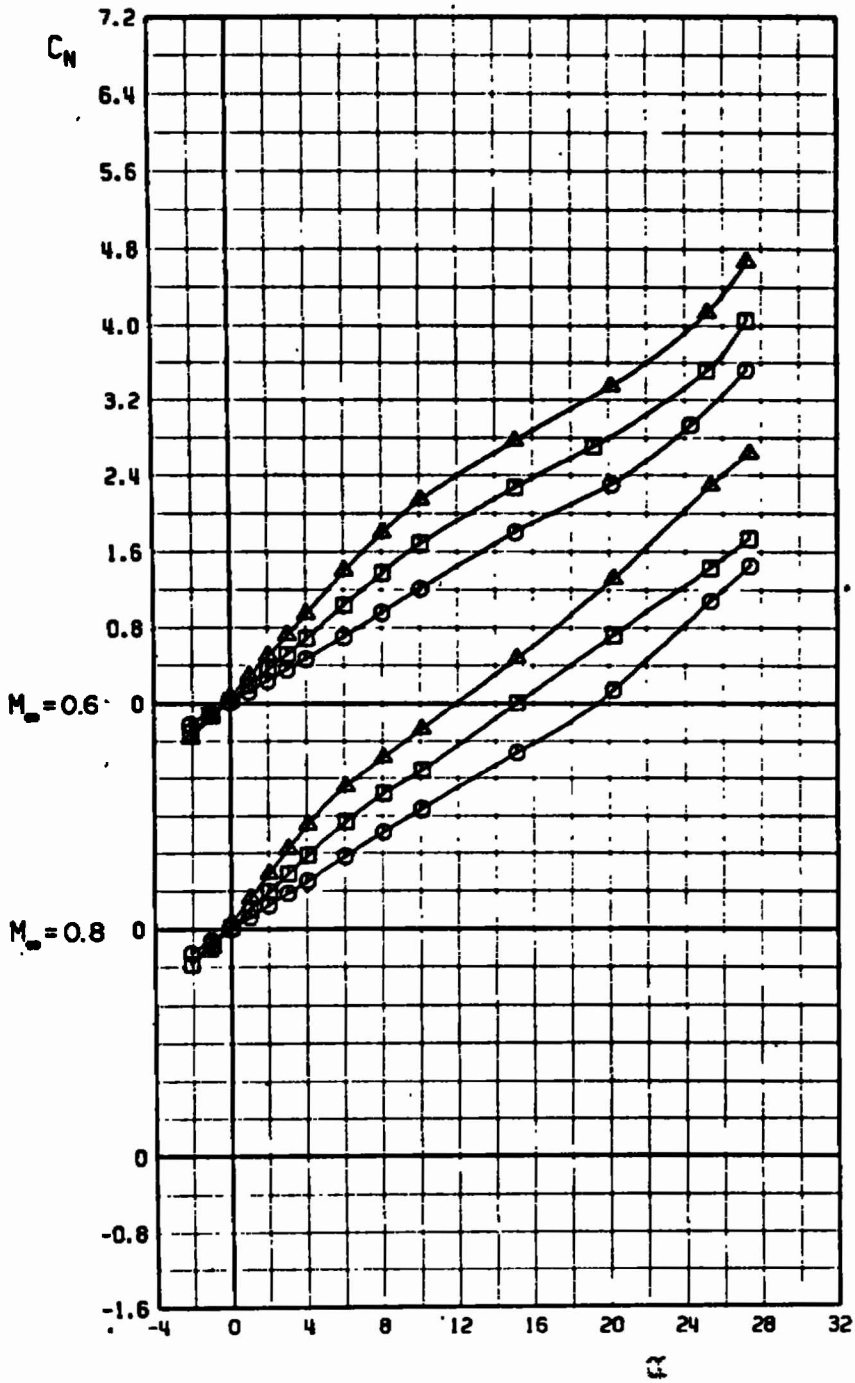
g.  $C_l$  versus  $\alpha$   
Fig. 8 Continued

	CONFIGURATION	b/D
○	N10 M4 R18	2.30
□	N10 M4 R18	2.68
△	N10 M4 R18	3.46



g. Concluded  
 Fig. 8 Concluded

CONFIGURATION	b/D
○	N10 M4 A23 2.66
□	N10 M4 A23 3.33
△	N10 M4 A23 4.00

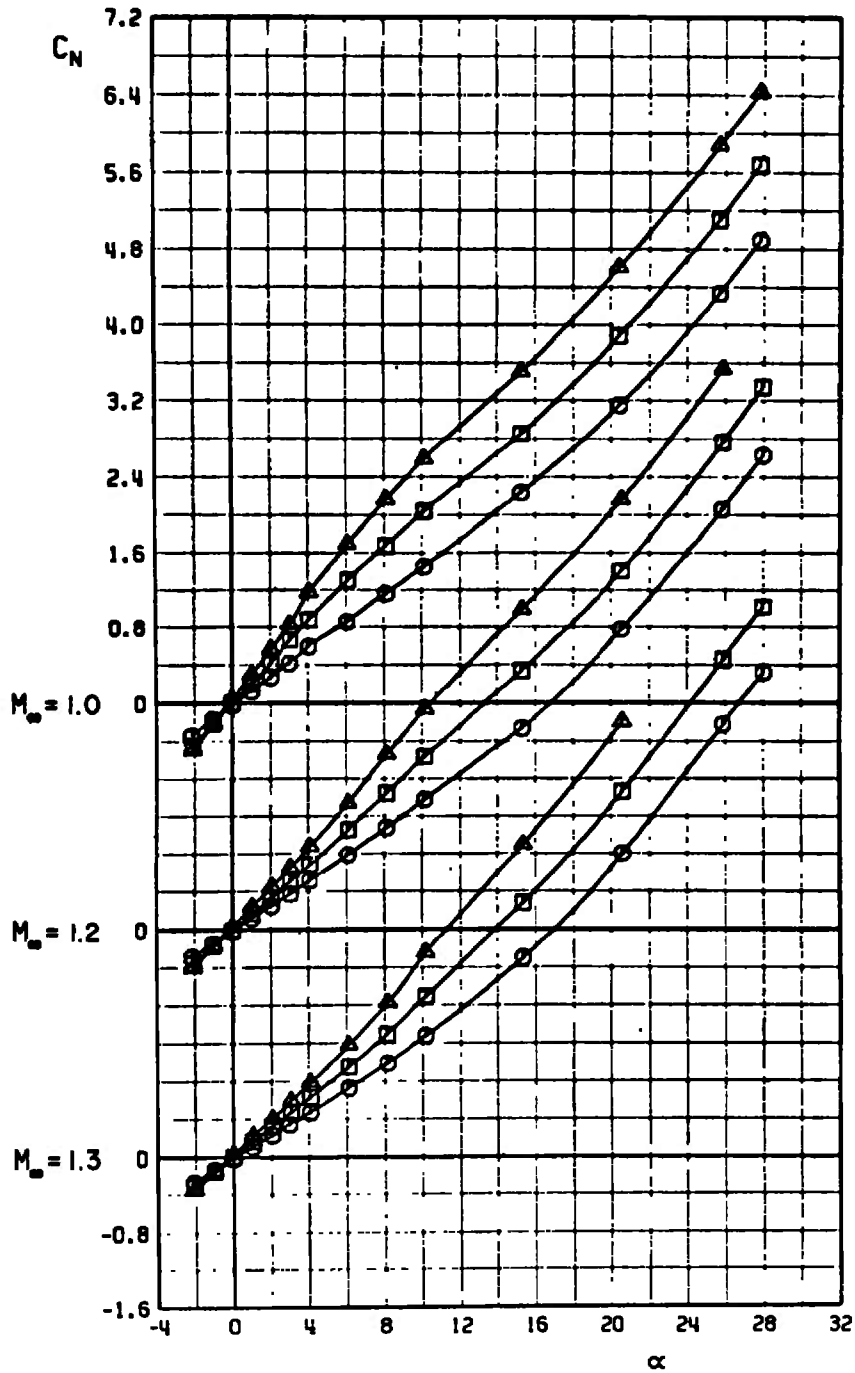


a.  $C_N$  versus  $\alpha$

Fig. 9 Aerodynamic Coefficients of Configurations N10M4A23, b/D = 2.66, 3.33, and 4.00



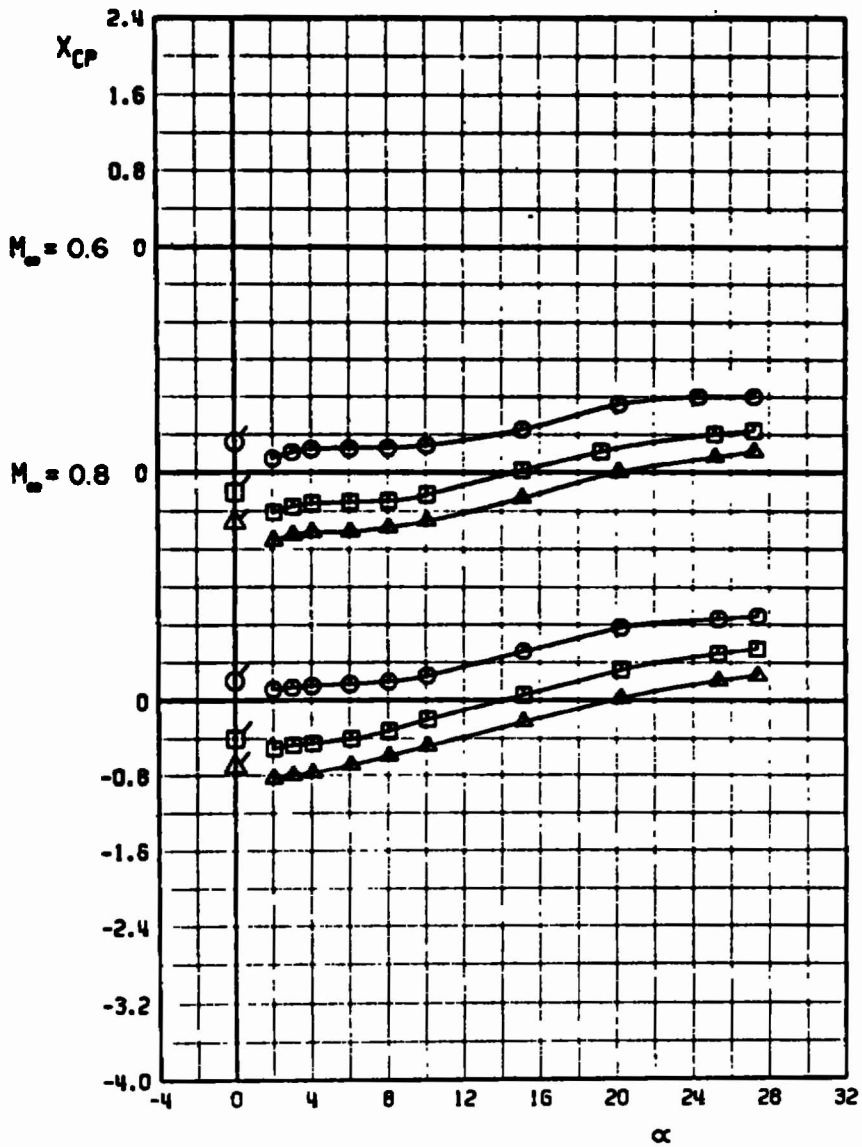
	CONFIGURATION	b/D
○	N10 M4 R23	2.66
□	N10 M4 R23	3.33
△	N10 M4 R23	4.00



a. Concluded  
Fig. 9 Continued

	CONFIGURATION	b/D
○	N10 M4 A23	2.66
□	N10 M4 A23	3.33
△	N10 M4 A23	4.00

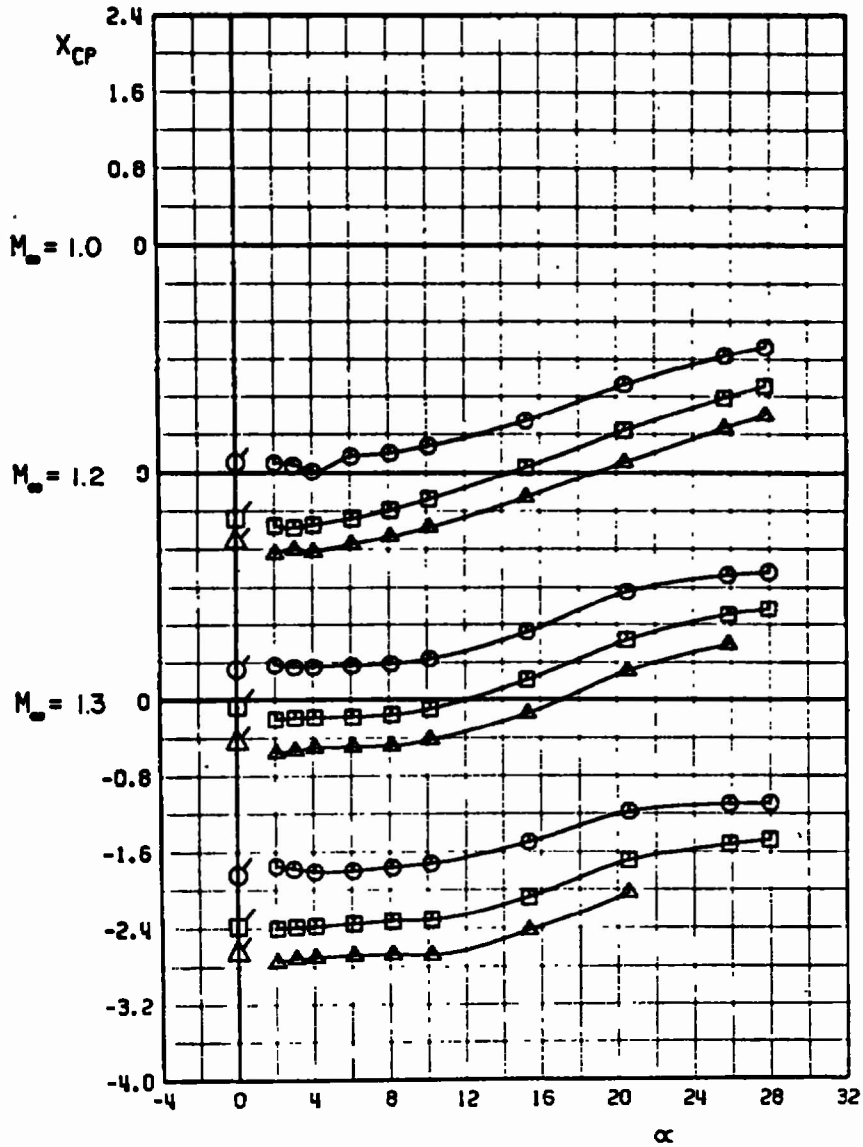
FLAGGED SYMBOLS DENOTE NEUTRAL-POINT LOCATIONS



b.  $X_{cp}$  versus  $\alpha$   
Fig. 9 Continued

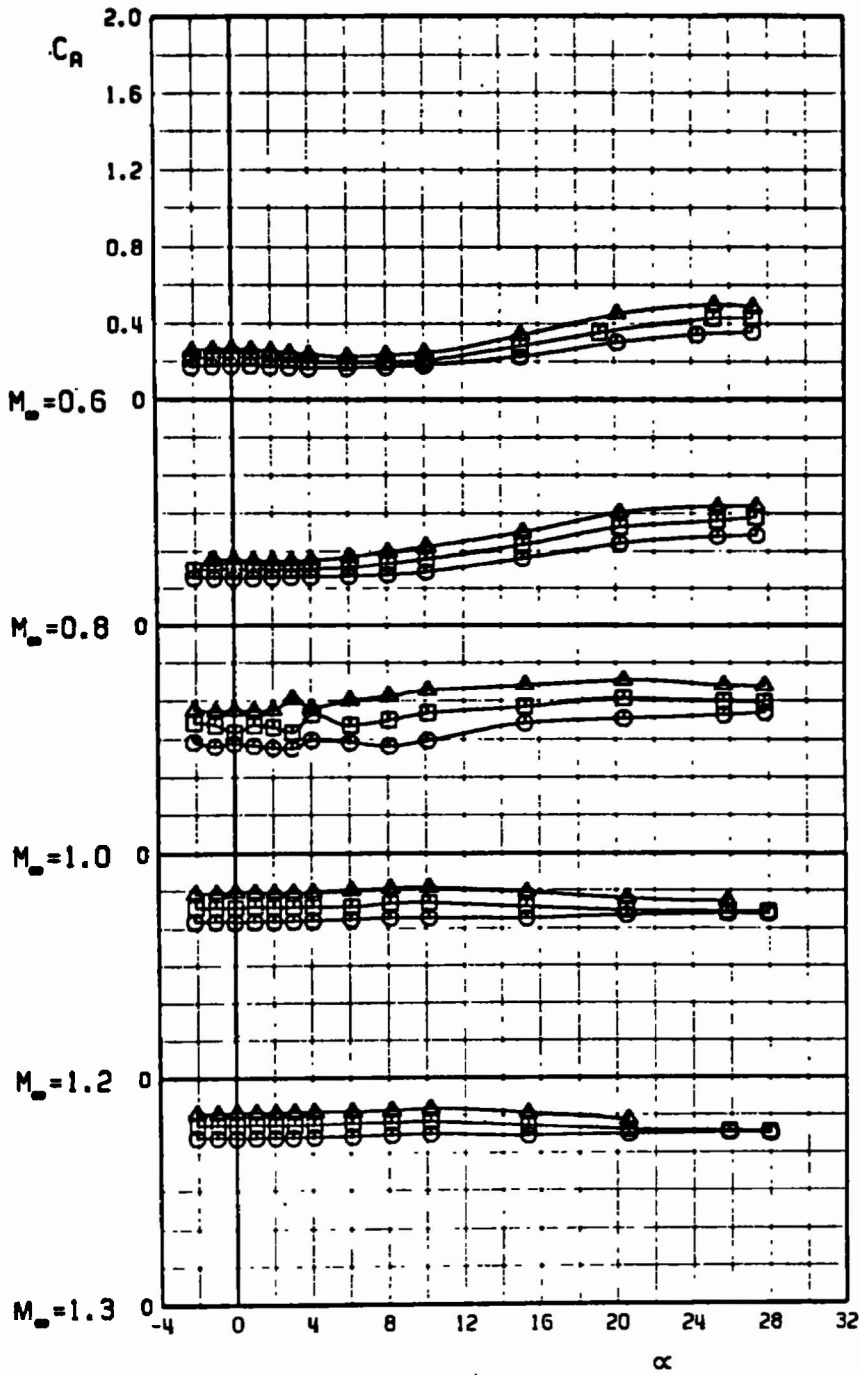
	CONFIGURATION	b/D
○	N10 M4 R23	2.66
□	N10 M4 R23	3.33
△	N10 M4 R23	4.00

FLAGGED SYMBOLS DENOTE NEUTRAL-POINT LOCATIONS



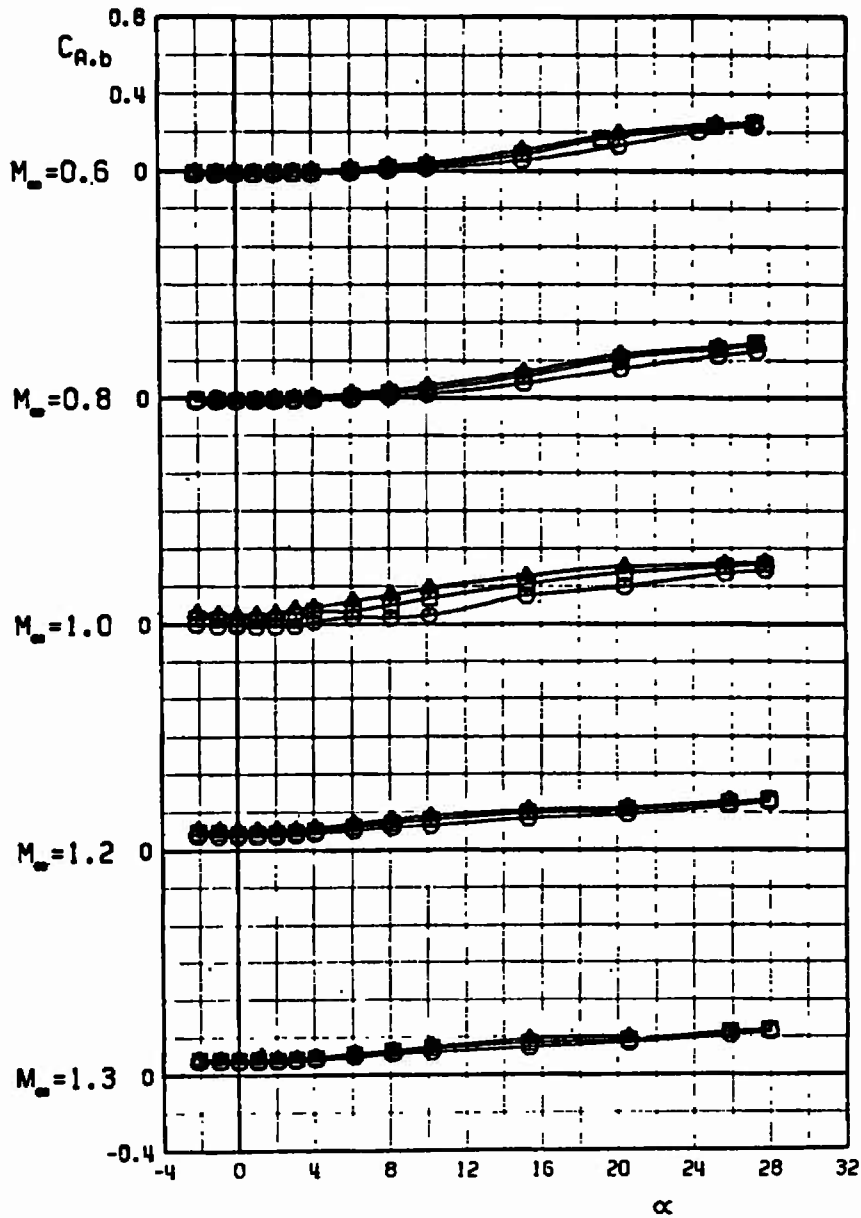
b. Concluded  
Fig. 9 Continued

CONFIGURATION b/D			
○	N10 M4 A23	2.66	
□	N10 M4 A23	3.33	
△	N10 M4 A23	4.00	



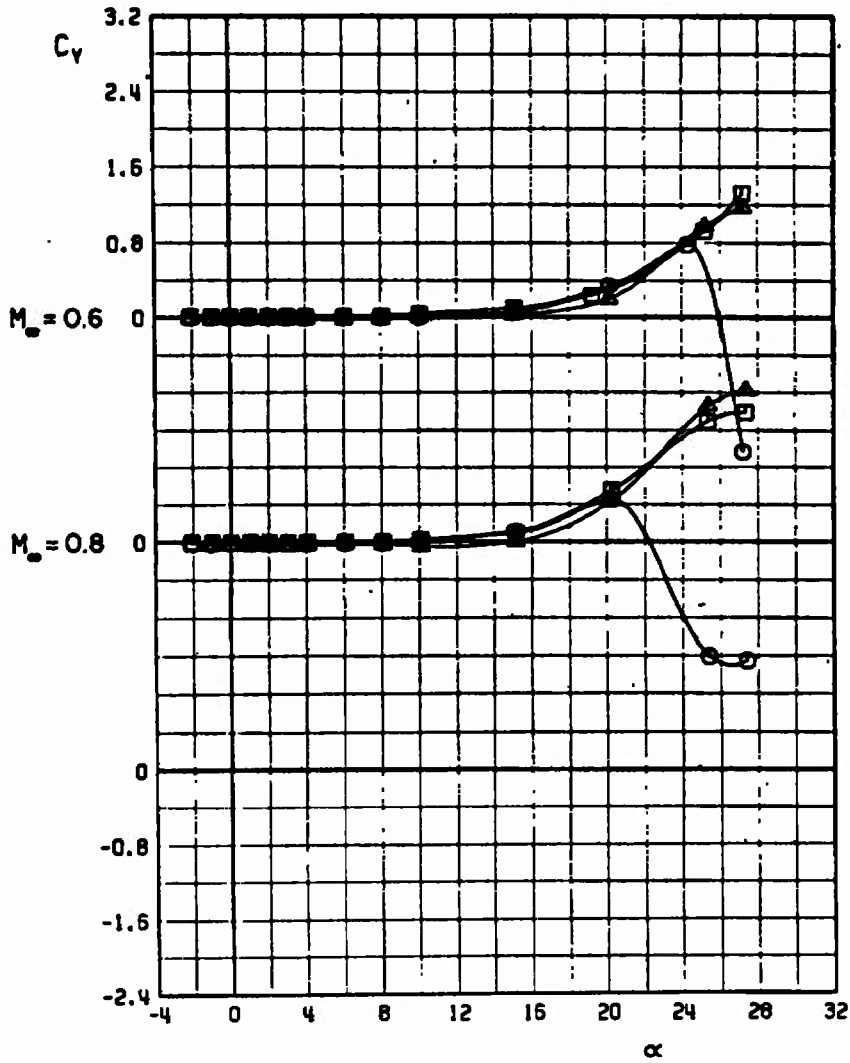
c.  $C_A$  versus  $\alpha$   
Fig. 9 Continued

	CONFIGURATION	b/D
○	N10 M4 A23	2.66
□	N10 M4 A23	3.33
△	N10 M4 A23	4.00



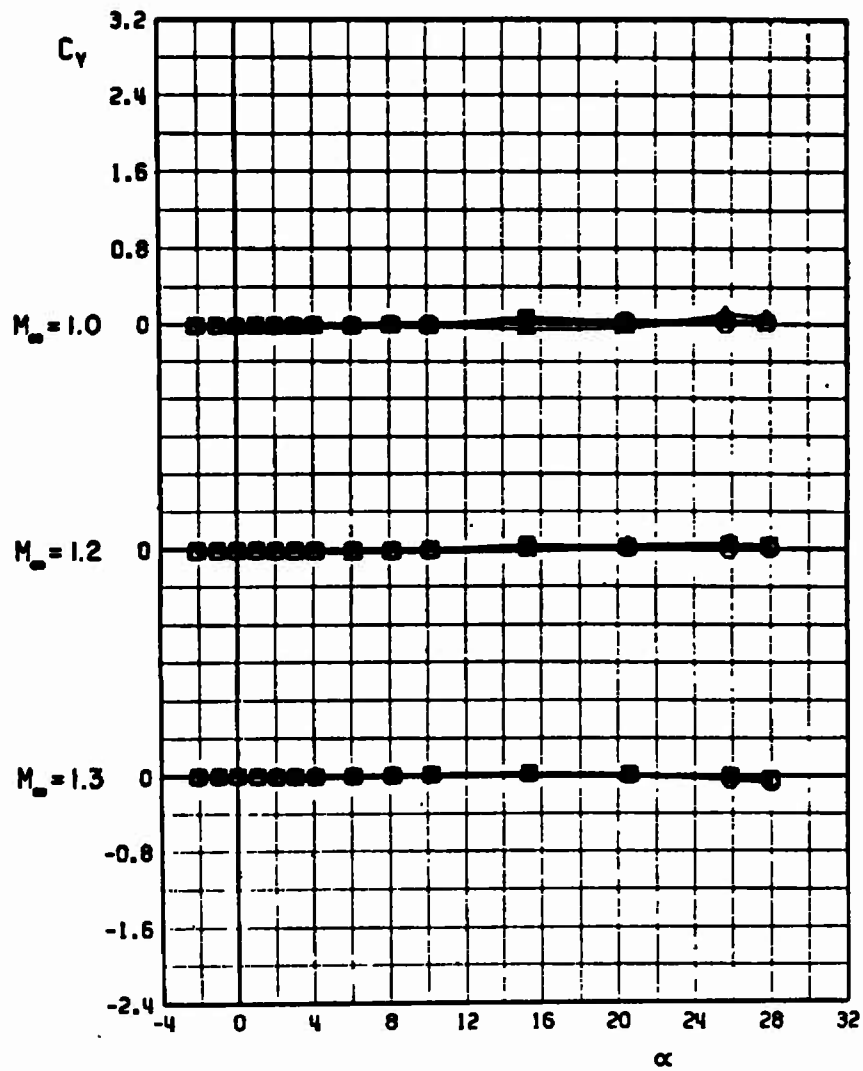
d.  $C_{A,b}$  versus  $\alpha$   
 Fig. 9 Continued

	CONFIGURATION	b/D
○	N10 M4 R23	2.66
□	N10 M4 R23	3.33
△	N10 M4 R23	4.00



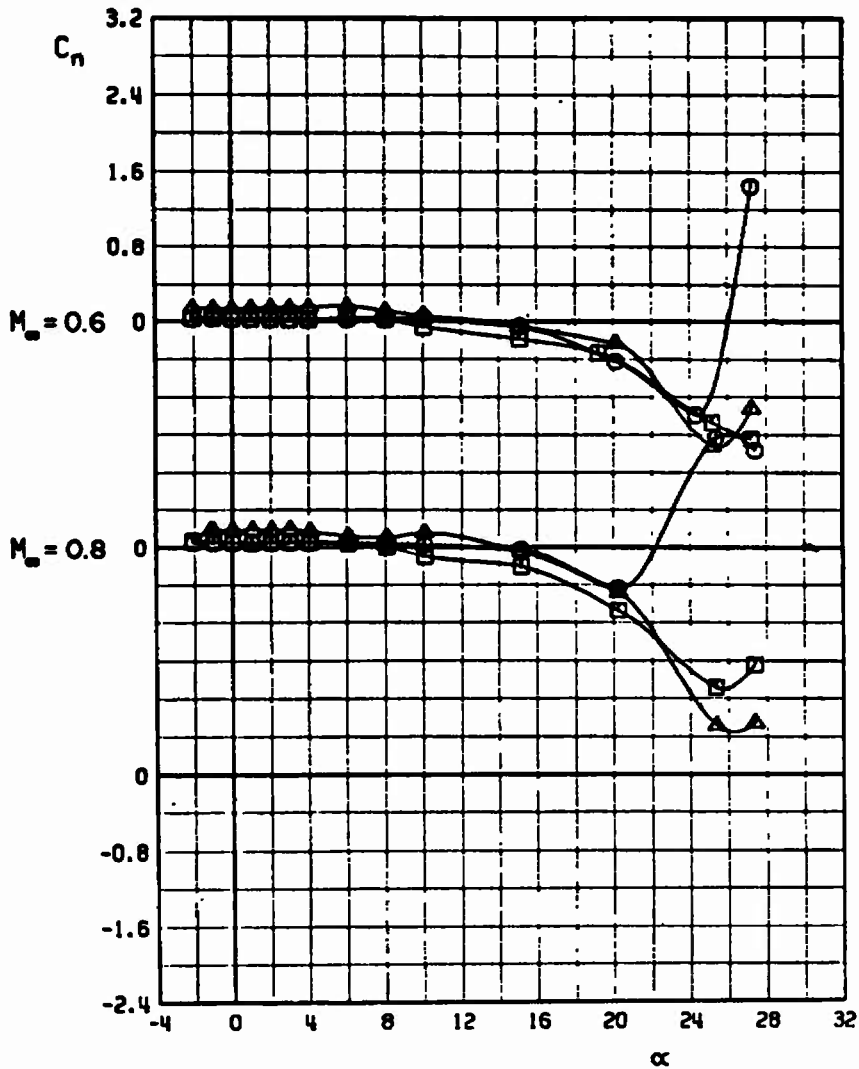
e.  $C_y$  versus  $\alpha$   
 Fig. 9 Continued

	CONFIGURATION	b/D
○	N10 M4 R23	2.66
□	N10 M4 R23	3.33
△	N10 M4 R23	4.00



e. Concluded  
Fig. 9 Continued

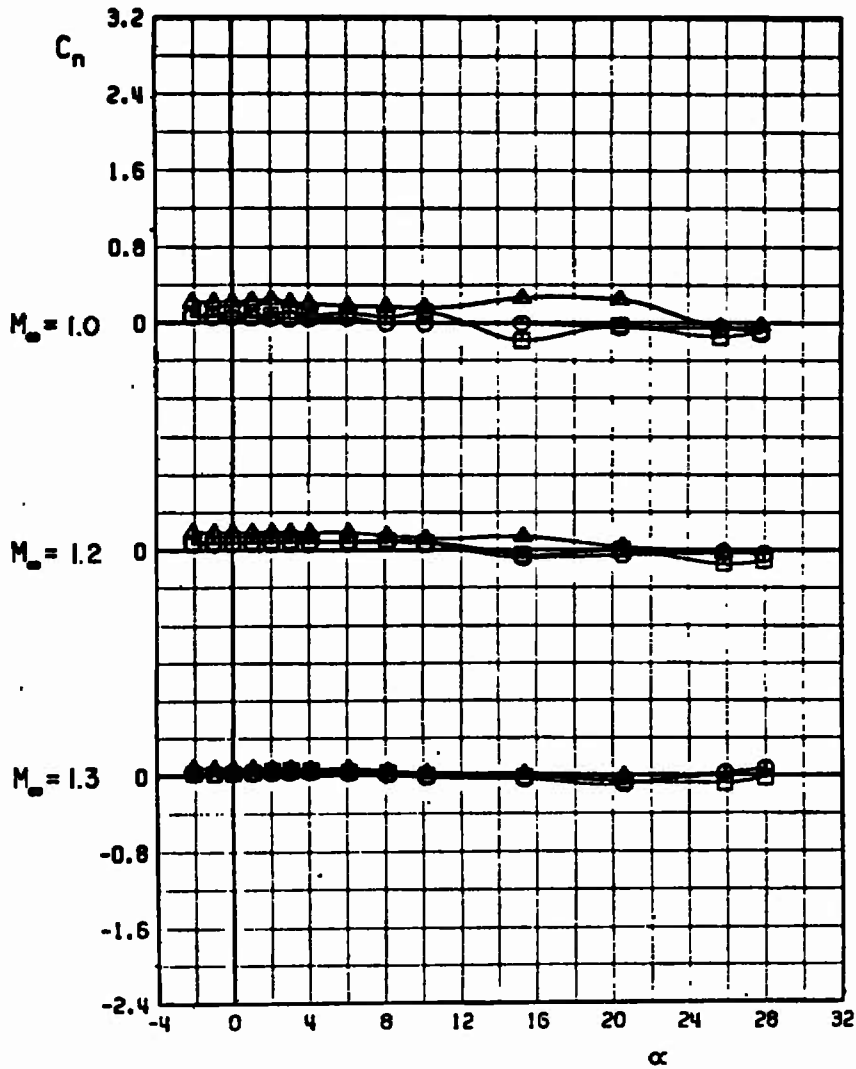
	CONFIGURATION	b/D
○	N10 M4 R23	2.66
□	N10 M4 R23	3.33
△	N10 M4 R23	4.00



f.  $C_n$  versus  $\alpha$   
Fig. 9 Continued

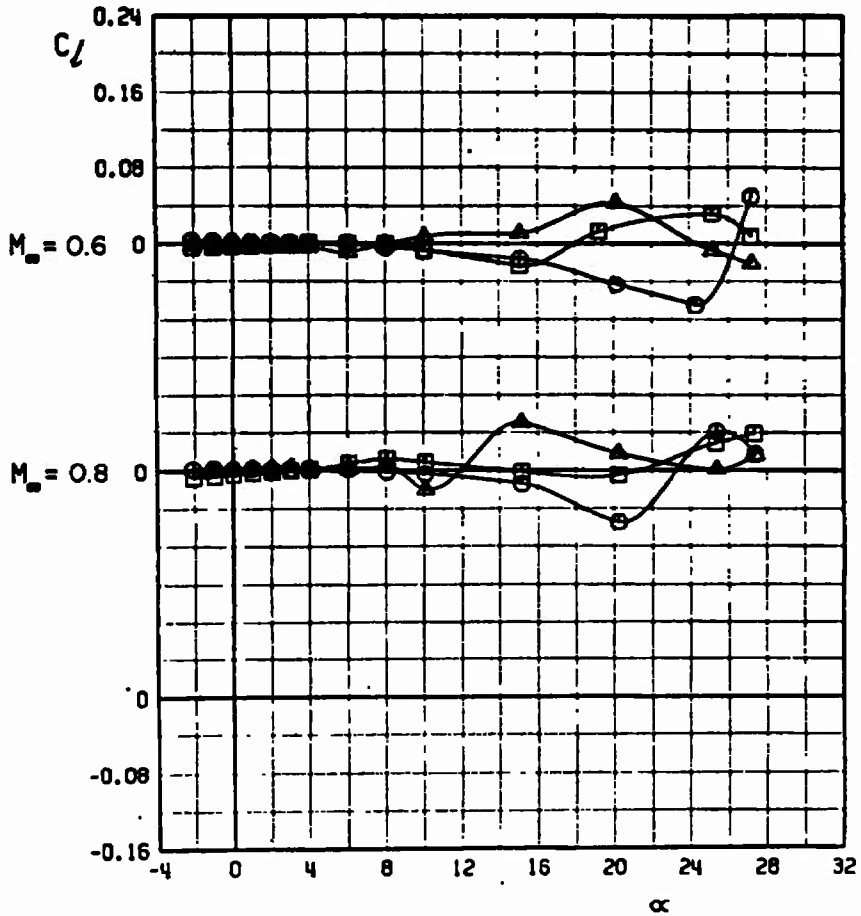


	CONFIGURATION	b/D
○	N10 M4 R23	2.66
□	N10 M4 R23	3.33
△	N10 M4 R23	4.00



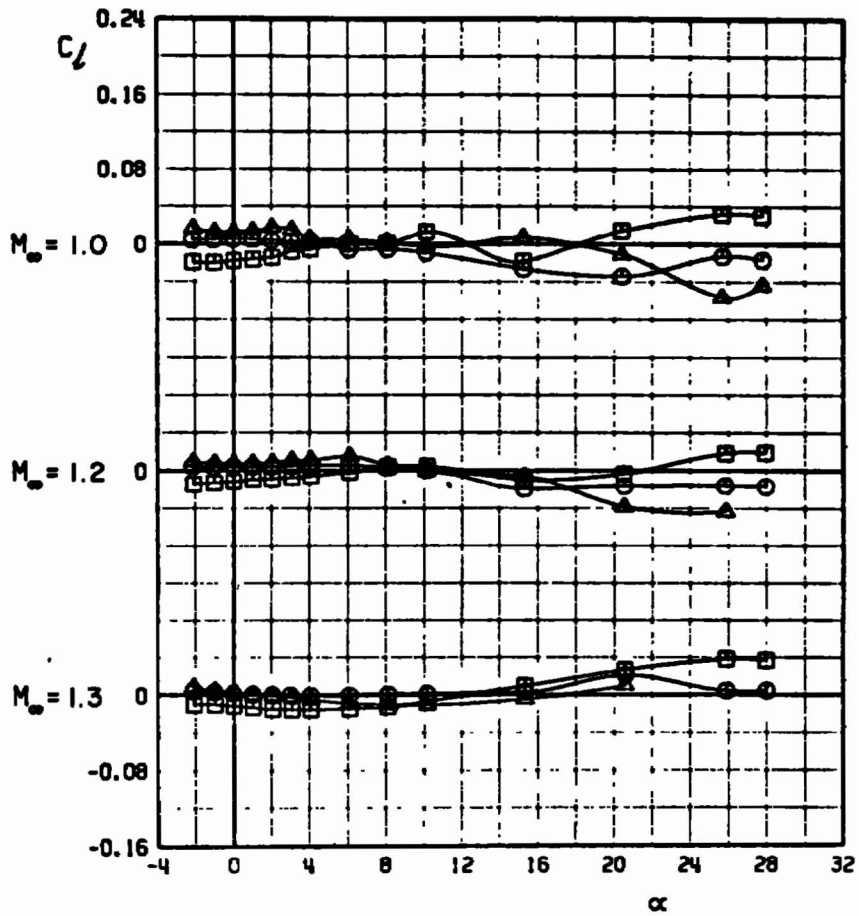
f. Concluded  
Fig. 9 Continued

	CONFIGURATION	b/D
○	N10 M4 R23	2.66
□	N10 M4 R23	3.33
△	N10 M4 R23	4.00



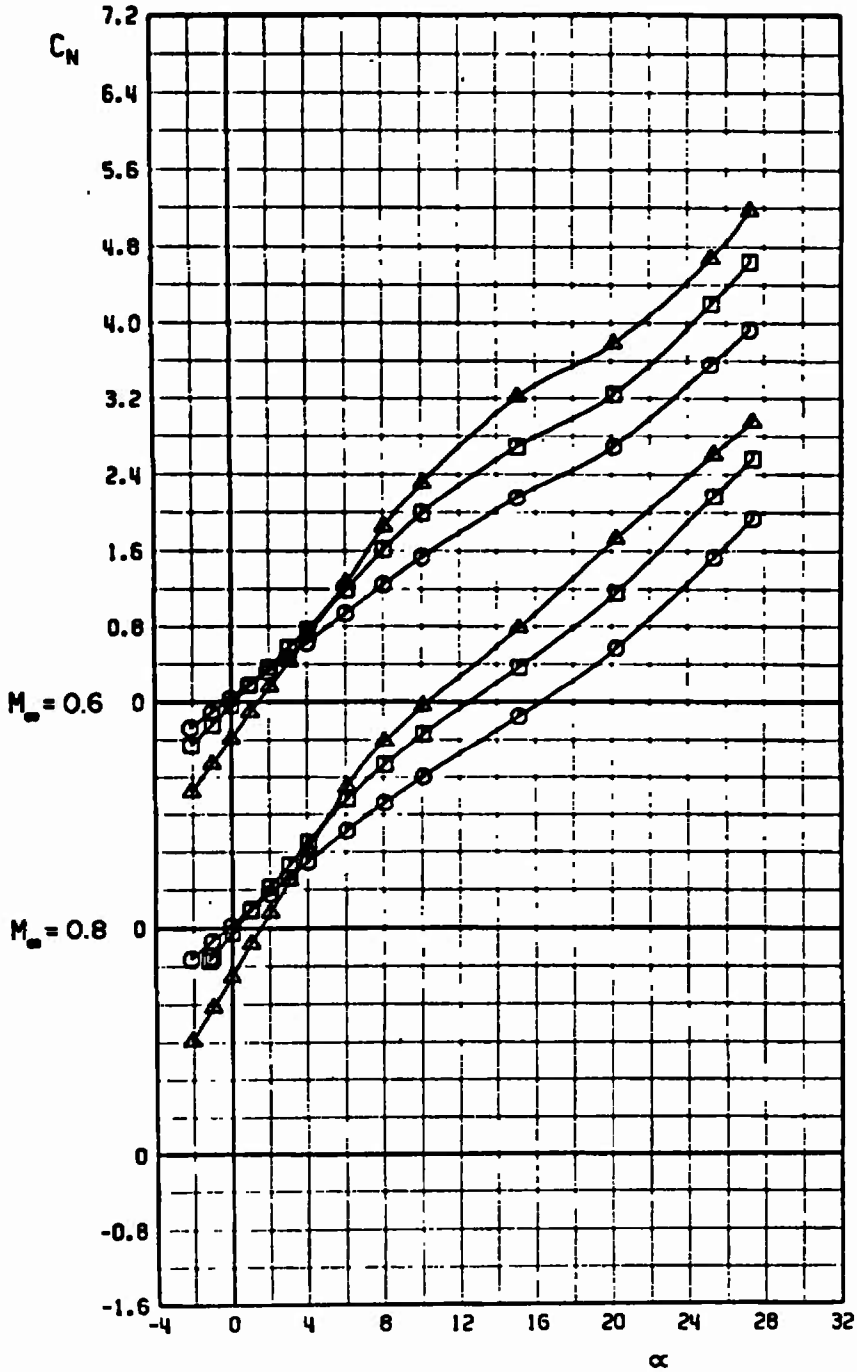
g.  $C_l$  versus  $\alpha$   
 Fig. 9 Continued

	CONFIGURATION	b/D
○	N10 M4 R23	2.66
□	N10 M4 R23	3.33
△	N10 M4 R23	4.00



g. Concluded  
Fig. 9 Concluded

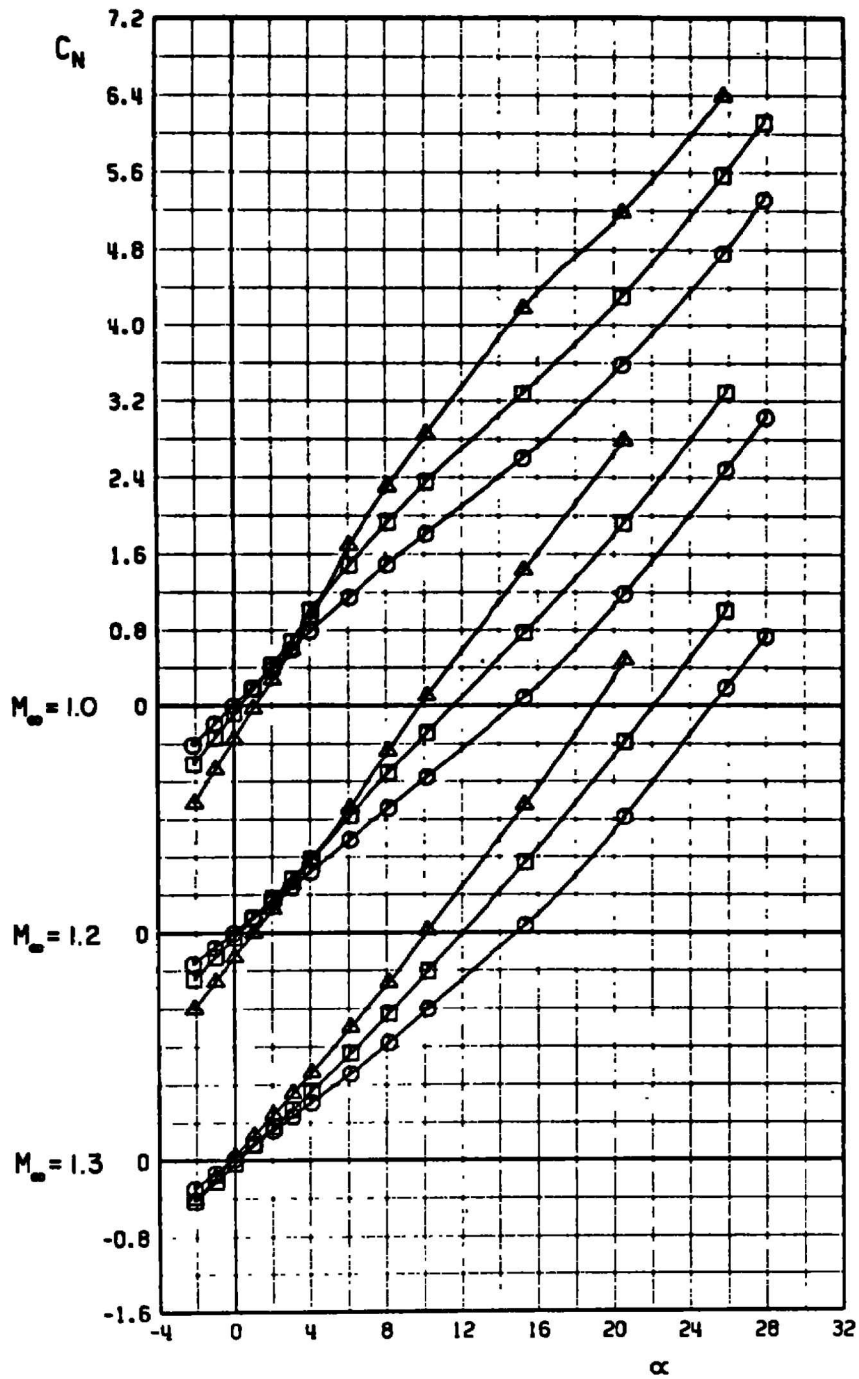
	CONFIGURATION	b/D
○	N10 M4 A24	2.66
□	N10 M4 A24	3.33
△	N10 M4 A24	4.00



a.  $C_N$  versus  $\alpha$

Fig. 10 Aerodynamic Coefficients of Configurations N10M4A24, b/D = 2.66, 3.33, and 4.00

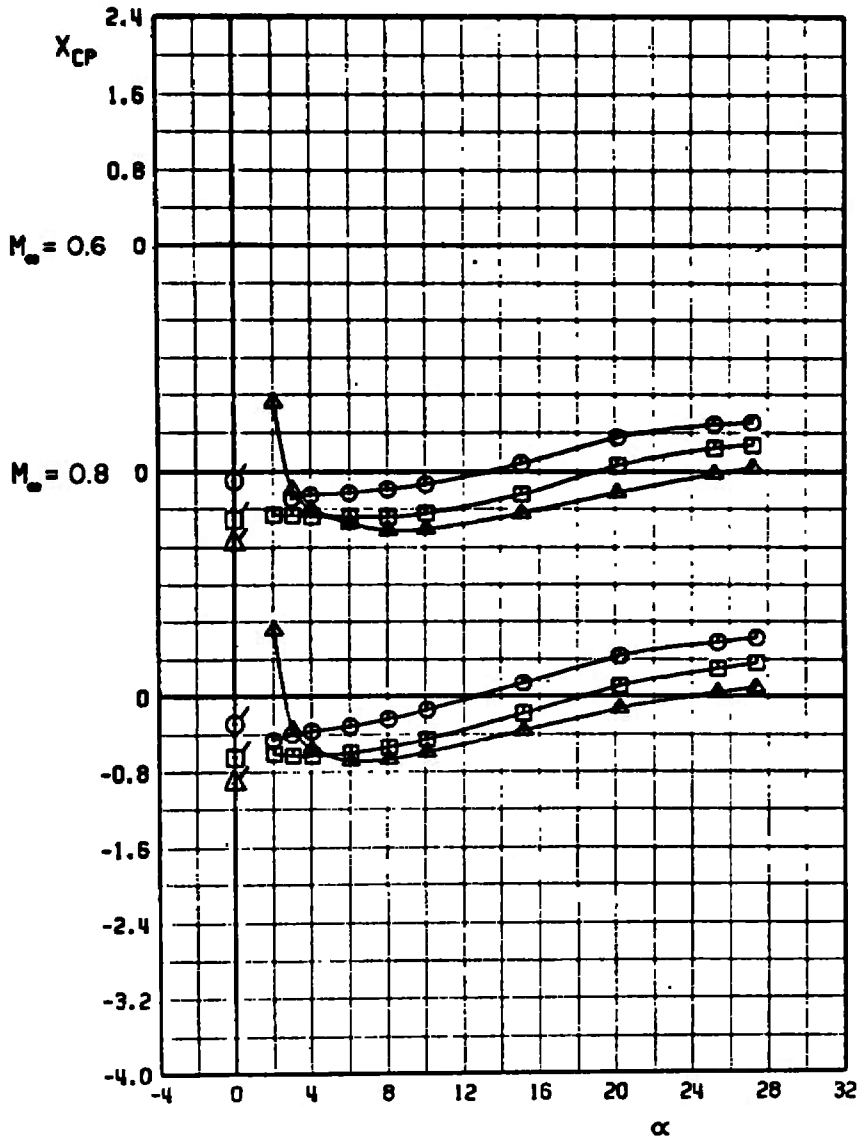
	CONFIGURATION	b/D
○	N10 M4 R24	2.66
□	N10 M4 R24	3.33
△	N10 M4 R24	4.00



a. Concluded  
Fig. 10 Continued

	CONFIGURATION	b/D
○	N10 M4 R24	2.66
□	N10 M4 R24	3.33
△	N10 M4 R24	4.00

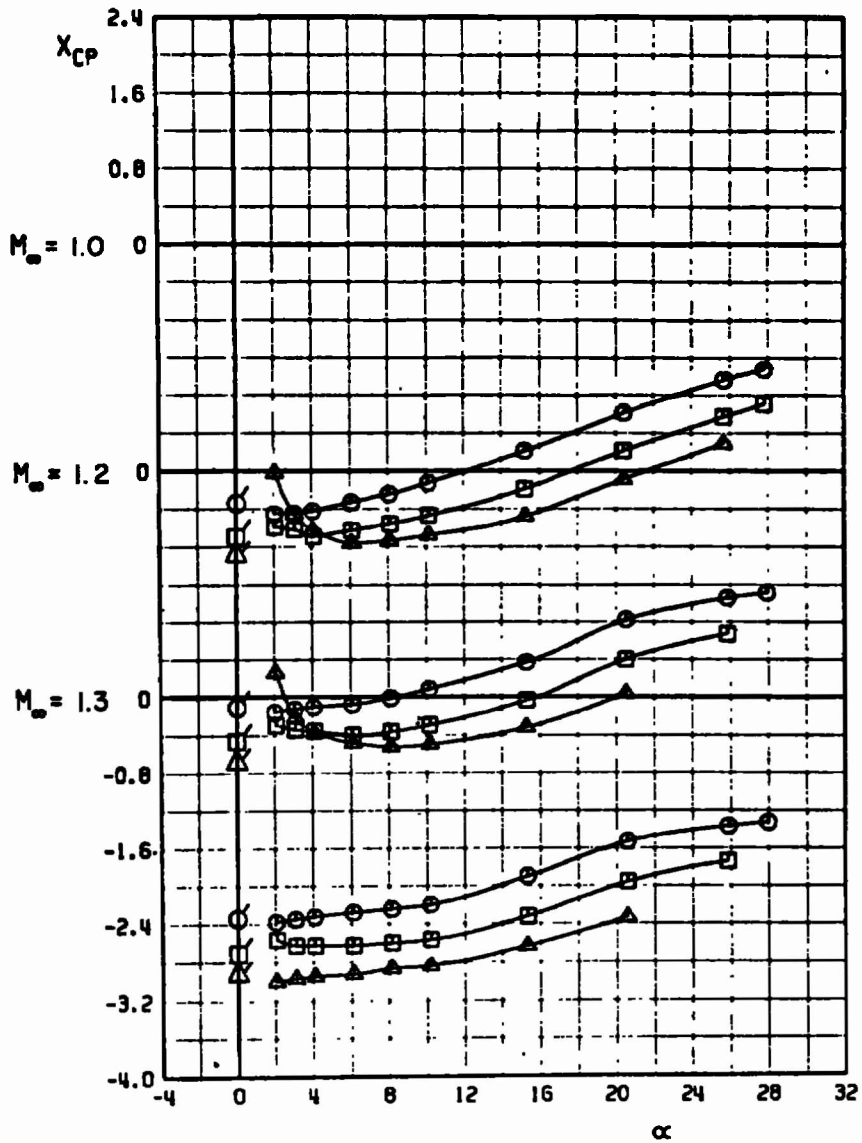
FLAGGED SYMBOLS DENOTE NEUTRAL-POINT LOCATIONS



b.  $X_{cp}$  versus  $\alpha$   
Fig. 10 Continued

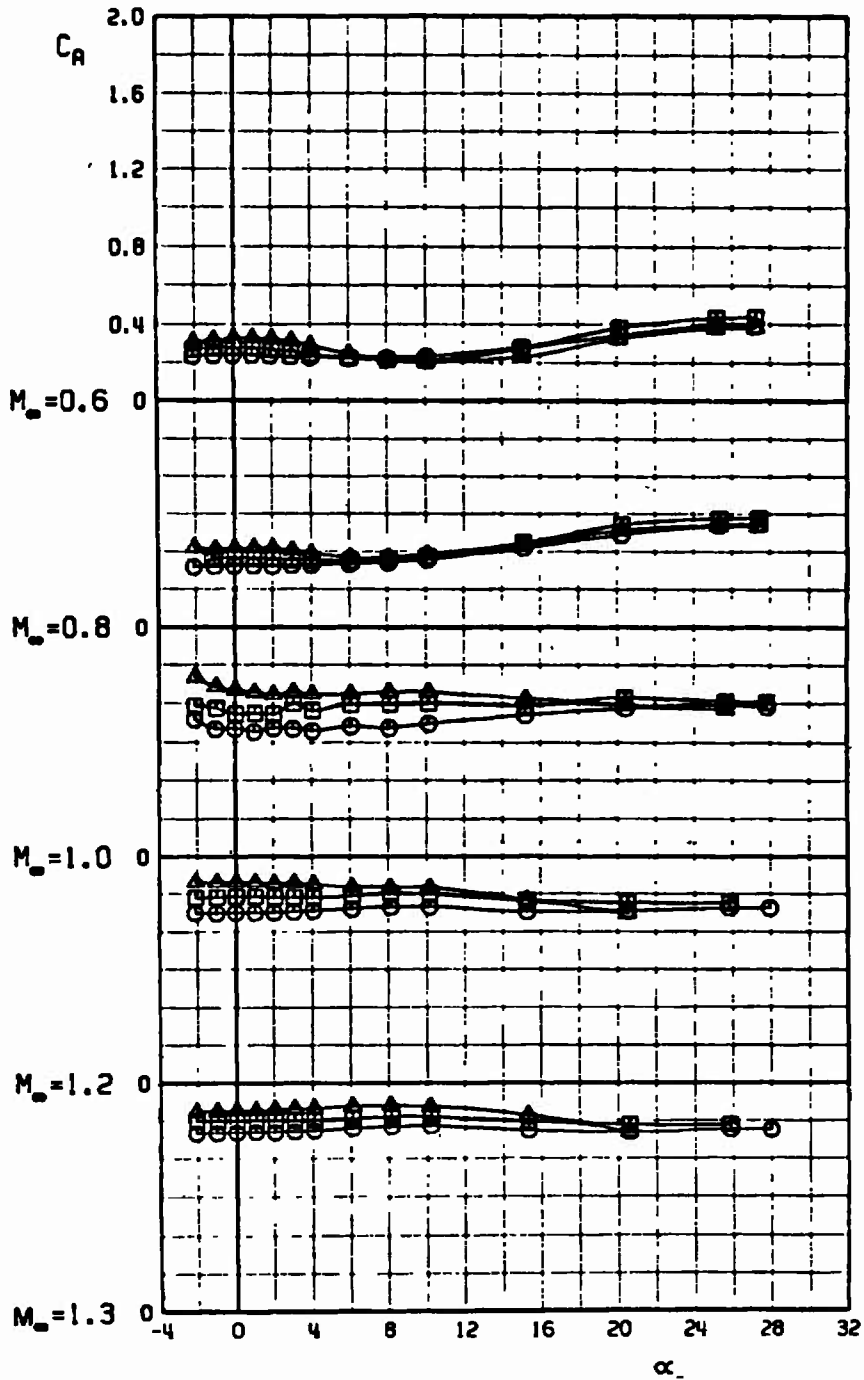
	CONFIGURATION	b/D
○	N10 M4 R24	2.66
□	N10 M4 R24	3.33
△	N10 M4 R24	4.00

FLAGGED SYMBOLS DENOTE NEUTRAL-POINT LOCATIONS



b. Concluded  
Fig. 10 Continued

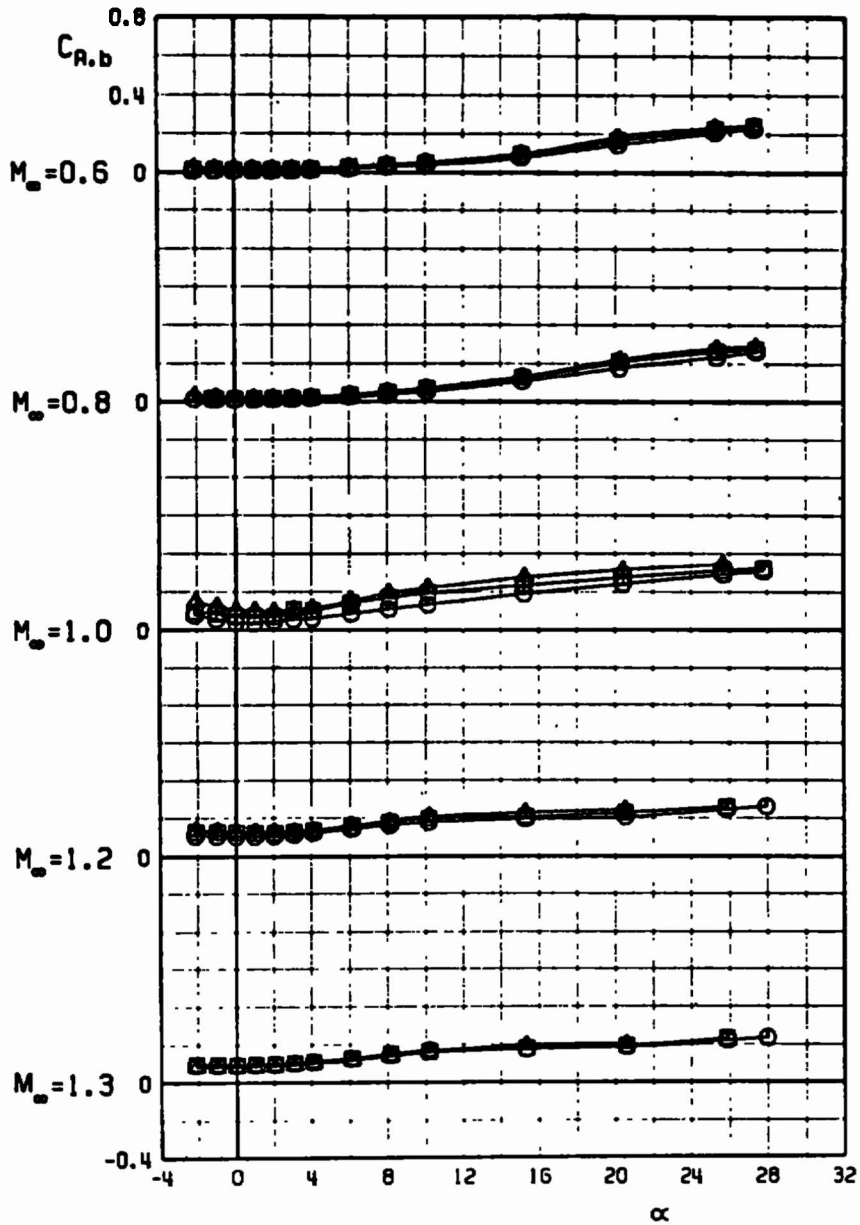
	CONFIGURATION	b/D
○	N10 M4 A24	2.66
□	N10 M4 A24	3.33
△	N10 M4 A24	4.00



c.  $C_A$  versus  $\alpha$   
 Fig. 10 Continued

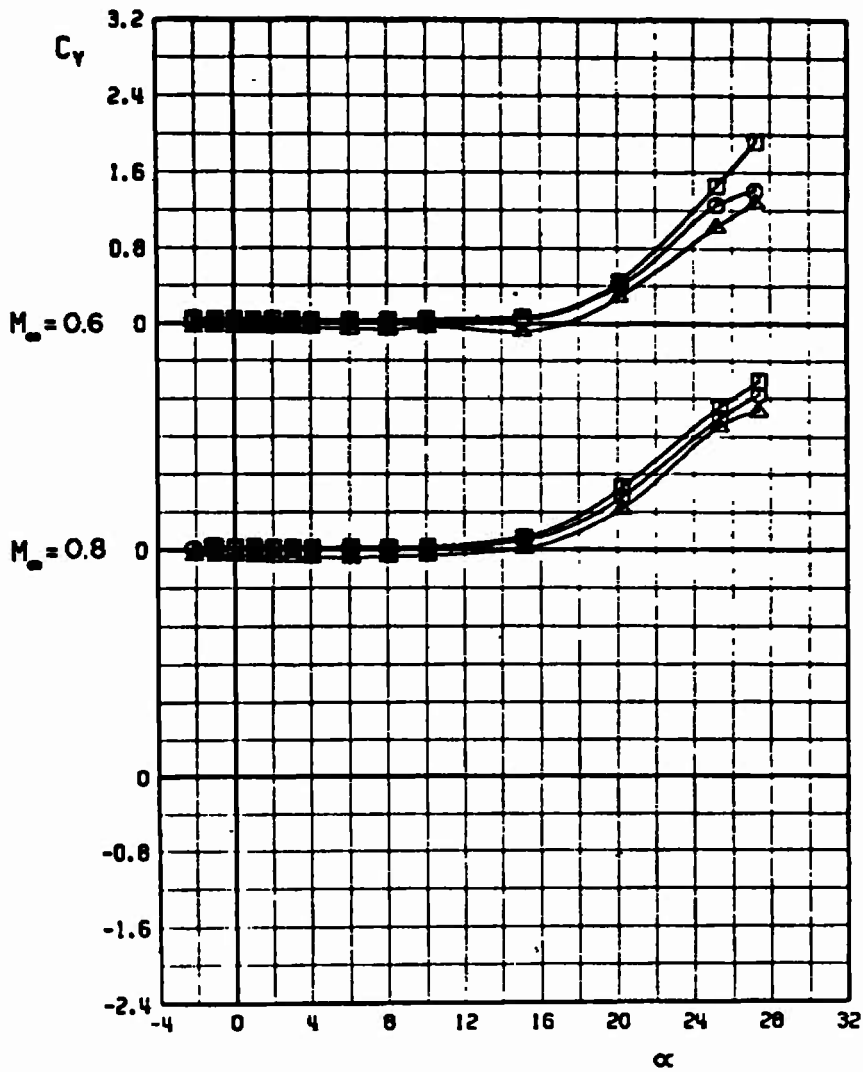


	CONFIGURATION	b/D
○	N10 M4 A24	2.66
□	N10 M4 A24	3.33
△	N10 M4 A24	4.00



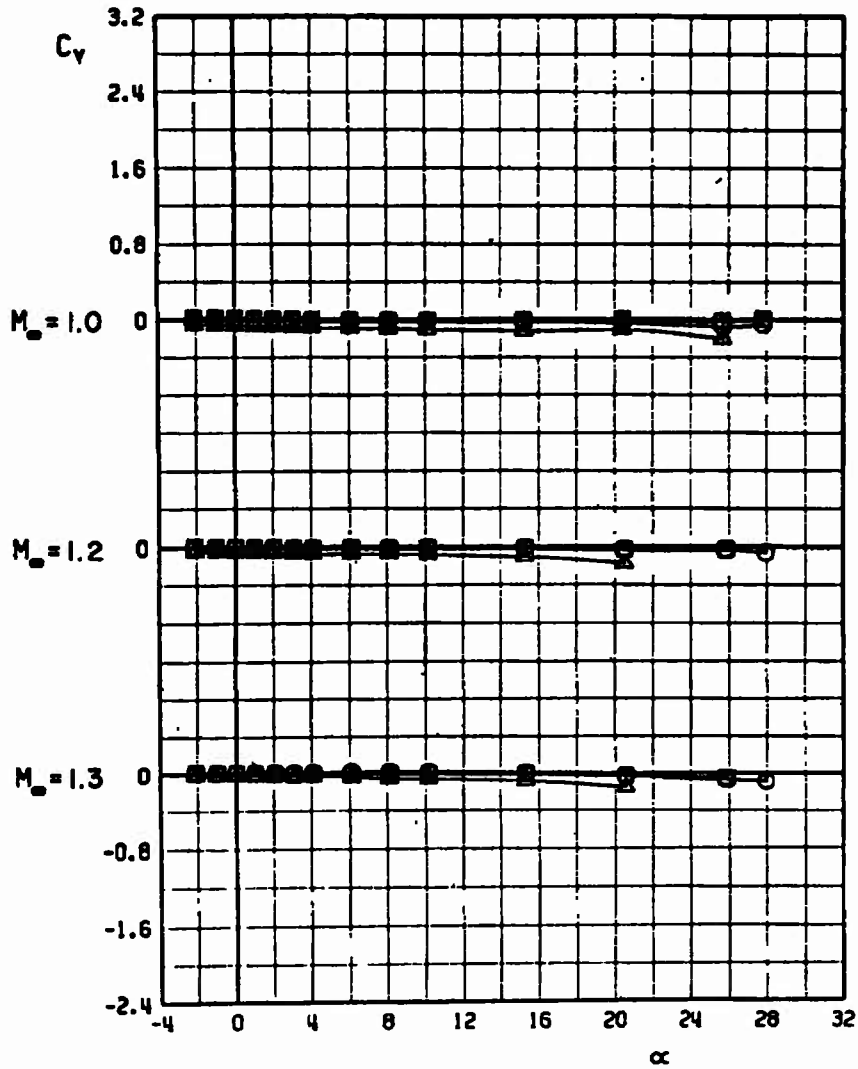
d.  $C_{A,b}$  versus  $\alpha$   
 Fig. 10 Continued

	CONFIGURATION	b/D
○	N10 M4 R24	2.66
□	N10 M4 R24	3.33
△	N10 M4 R24	4.00



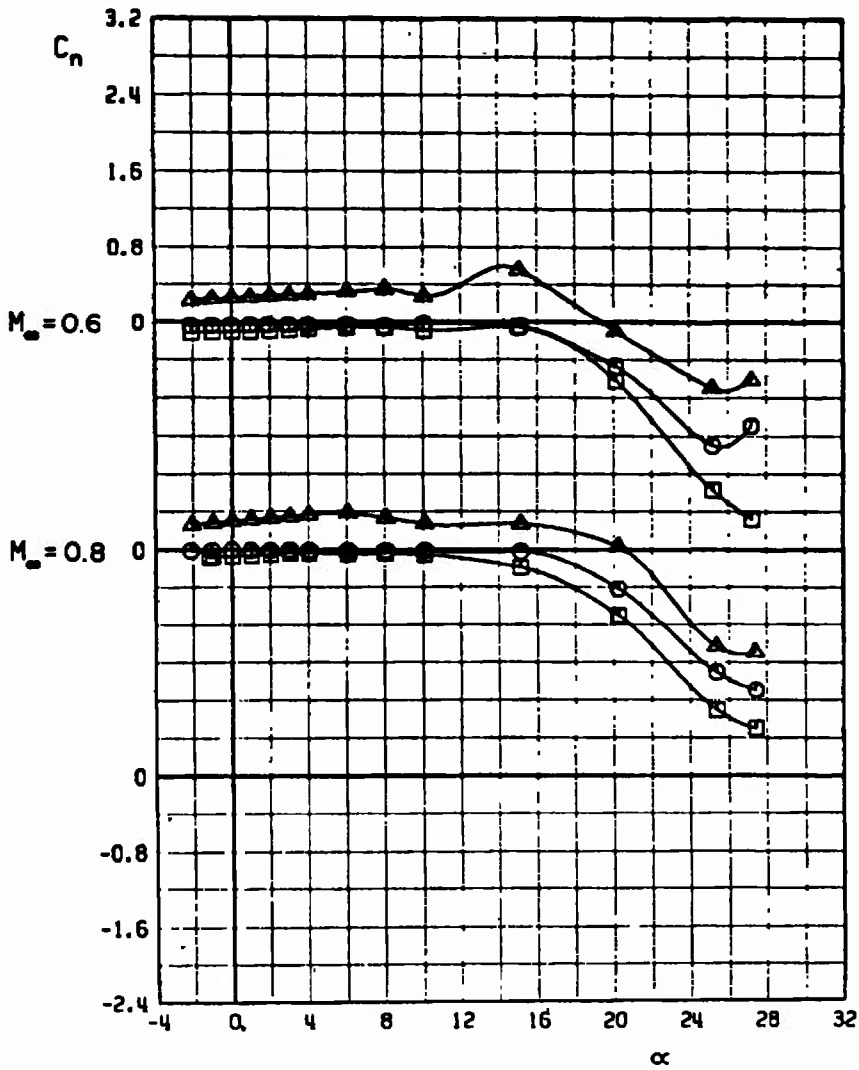
e.  $C_y$  versus  $\alpha$   
 Fig. 10 Continued

	CONFIGURATION	b/D
○	N10 M4 R24	2.66
□	N10 M4 R24	3.33
△	N10 M4 R24	4.00



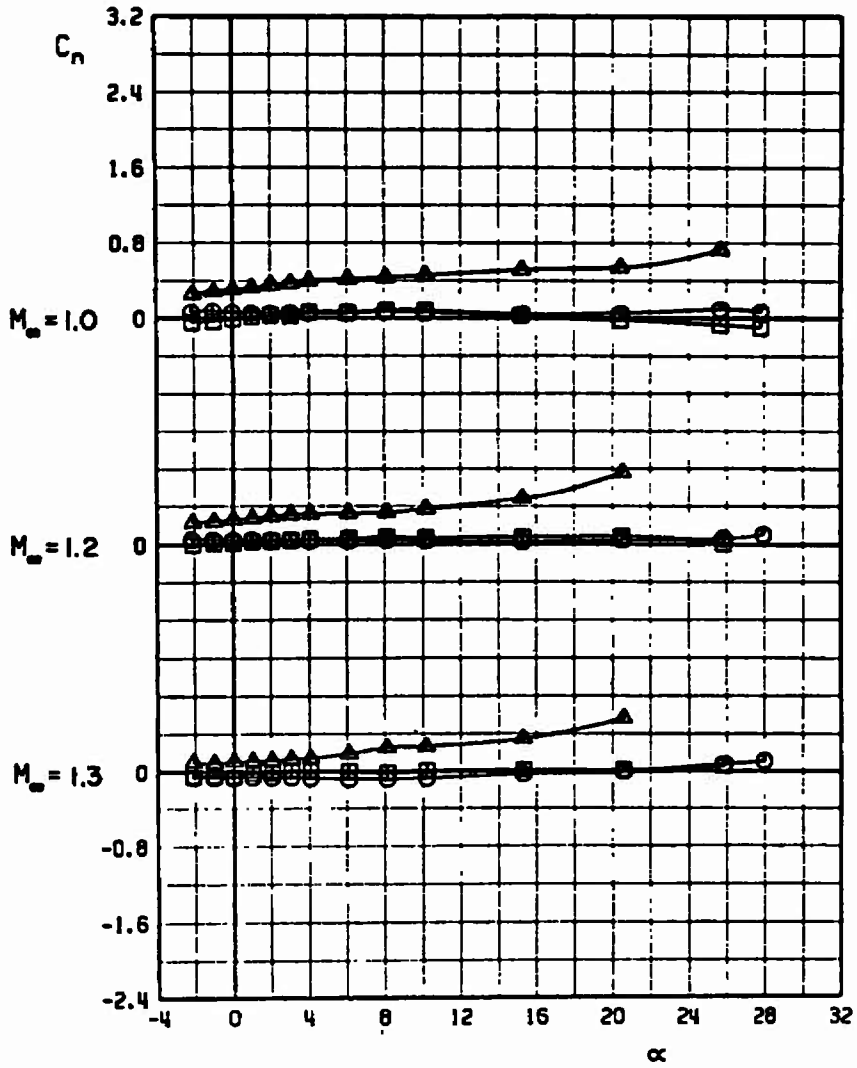
e. Concluded  
Fig. 10 Continued

	CONFIGURATION	b/D
○	N10 M4 R24	2.66
□	N10 M4 R24	3.33
△	N10 M4 R24	4.00



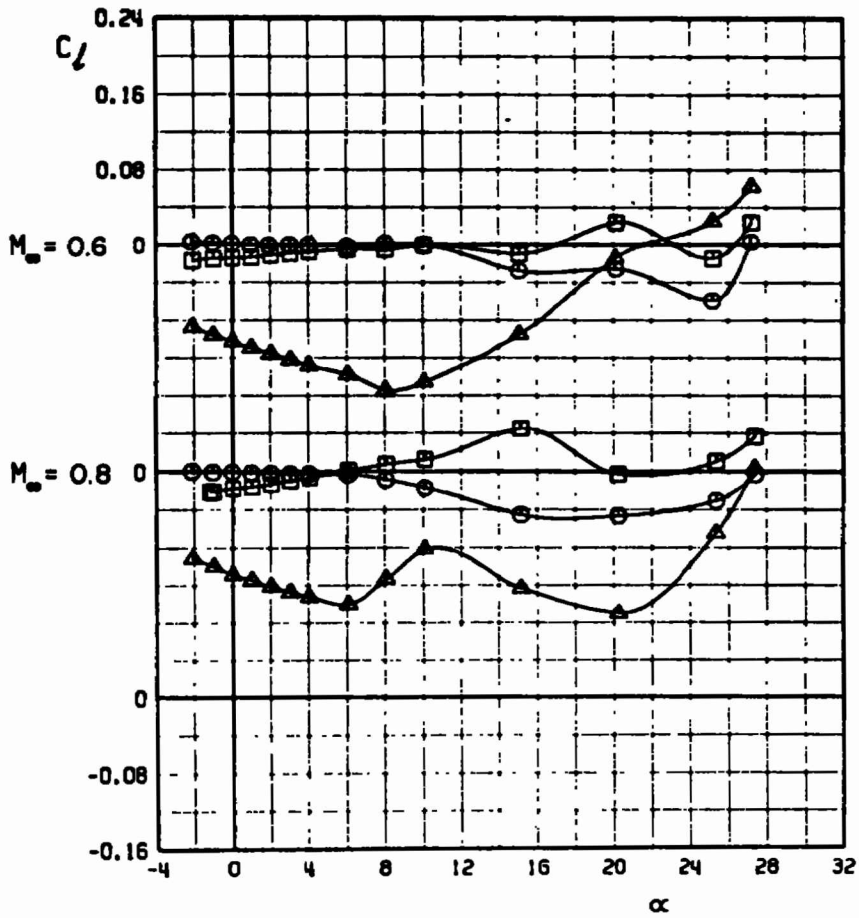
f.  $C_n$  versus  $\alpha$   
 Fig. 10 Continued

	CONFIGURATION	b/D
○	N10 M4 R24	2.66
□	N10 M4 R24	3.33
△	N10 M4 R24	4.00



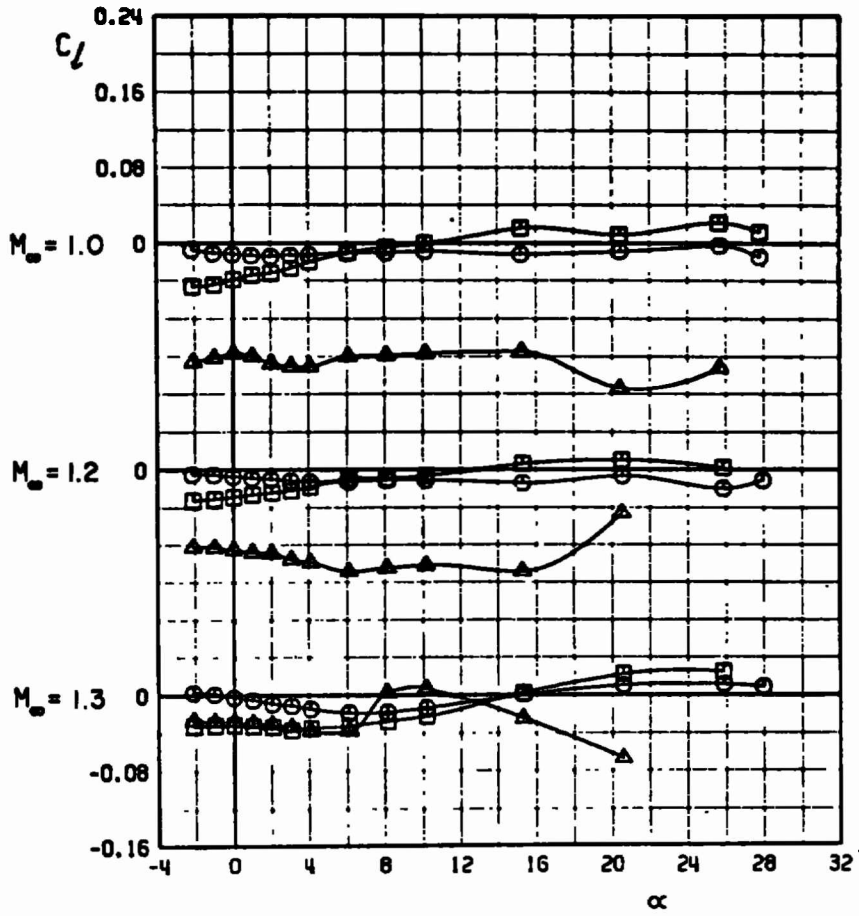
f. Concluded  
Fig. 10 Continued

	CONFIGURATION	b/D
○	N10 M4 A24	2.66
□	N10 M4 A24	3.33
△	N10 M4 A24	4.00



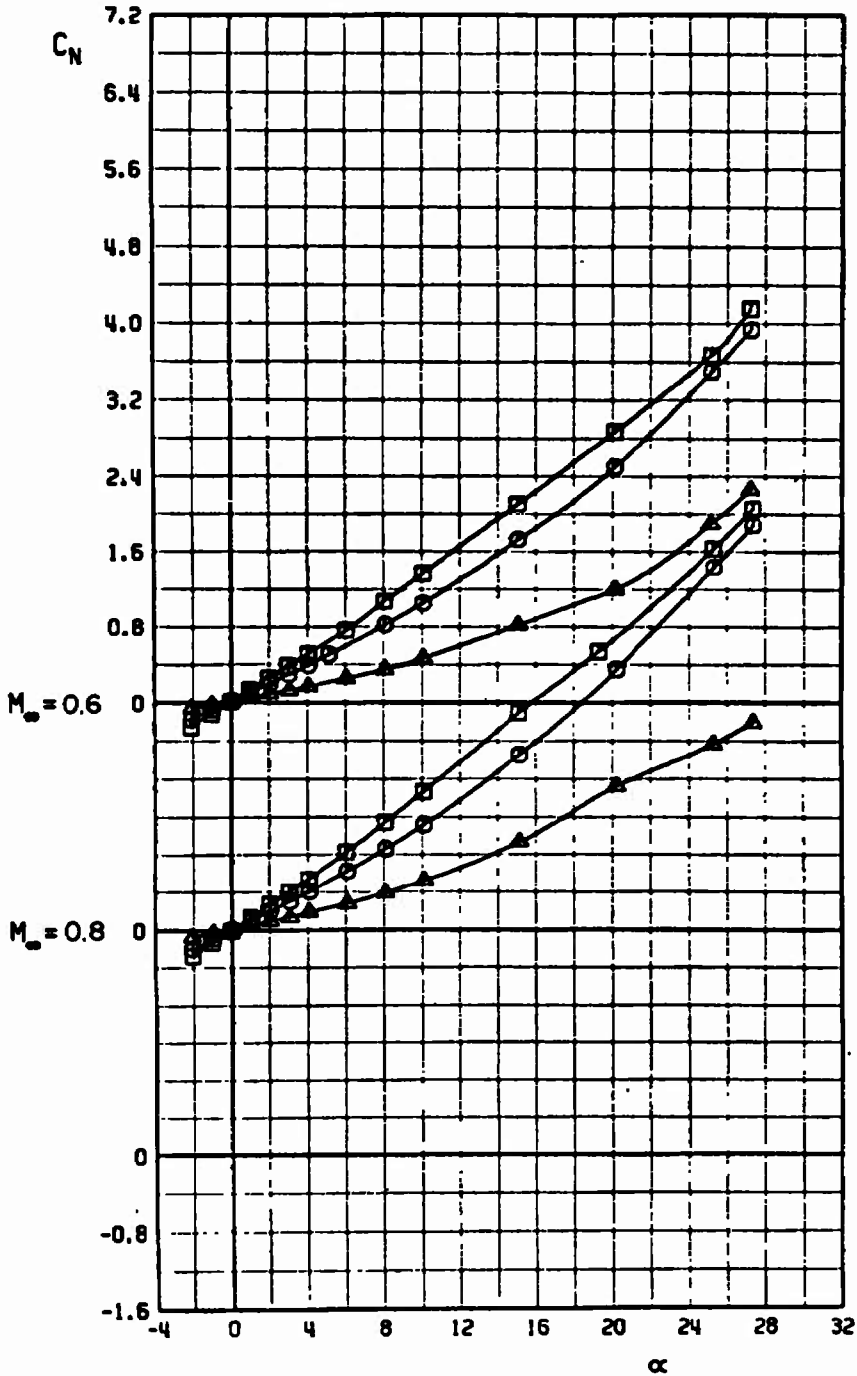
g.  $C_l$  versus  $\alpha$   
 Fig. 10 Continued

	CONFIGURATION	b/D
○	N10 M4 R24	2.66
□	N10 M4 R24	3.33
△	N10 M4 R24	4.00



g. Concluded  
 Fig. 10 Concluded

	CONFIGURATION	b/D
□	N10 M4 A1	2.20
○	N10 M4 A6	1.80
△	N10 M5 A17	1.00

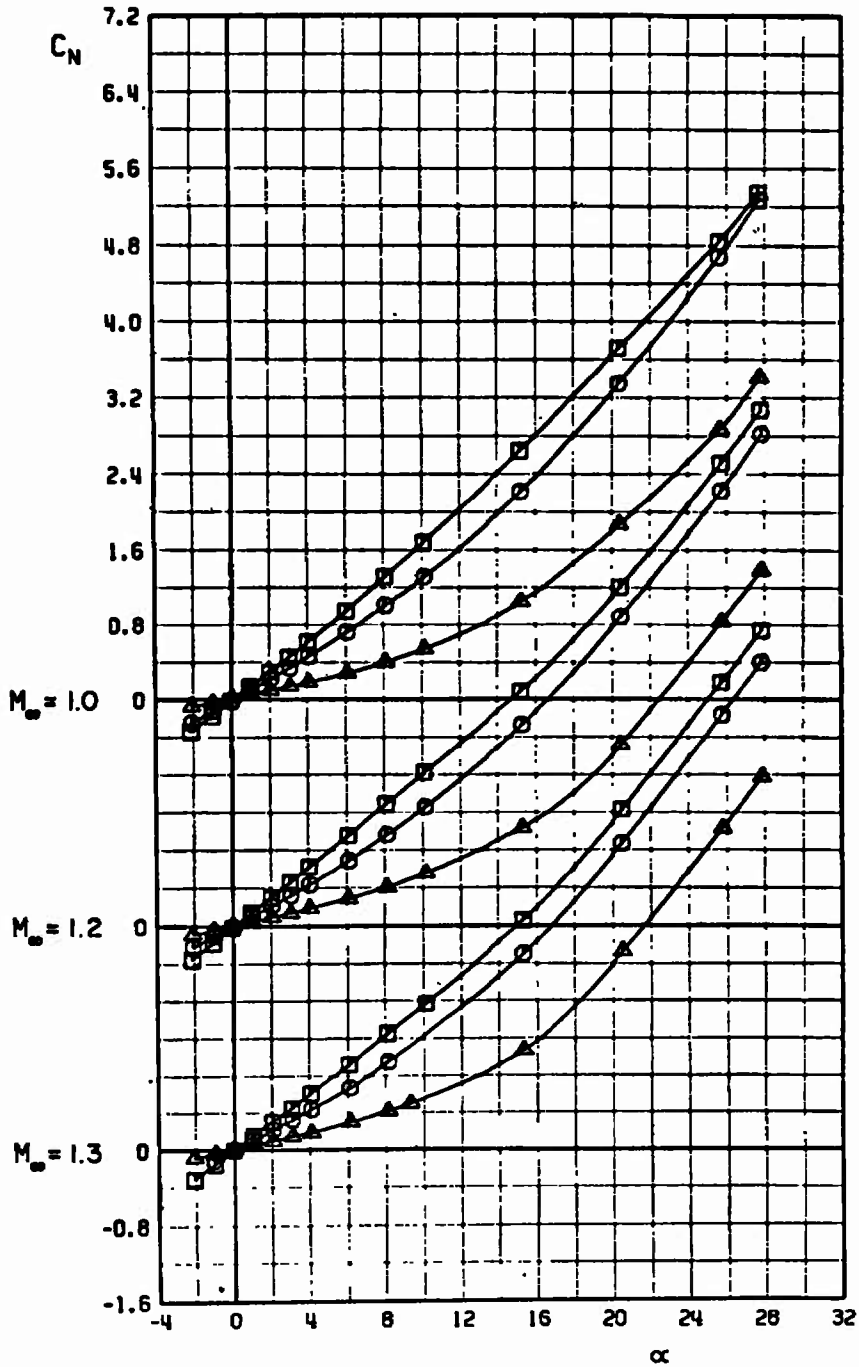


a.  $C_N$  versus  $\alpha$

Fig. 11 Aerodynamic Coefficients of Configuration N10M4A1,  $b/D = 2.20$ , Configuration N10M4A6,  $b/D = 1.80$ , and Configuration N10M5A17,  $b/D = 1.00$



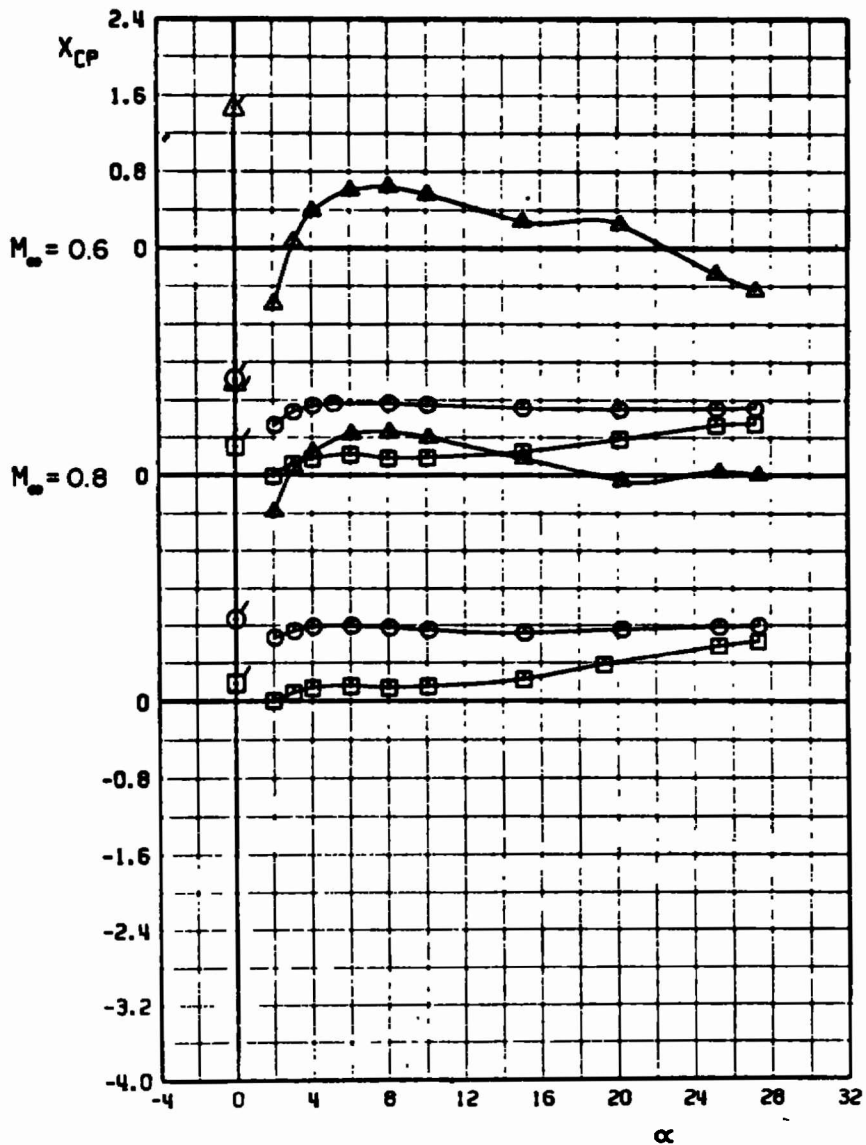
	CONFIGURATION	b/D
□	N10 M4 A1	2.20
○	N10 M4 A6	1.80
△	N10 M5 A17	1.00



a. Concluded  
Fig. 11 Continued

CONFIGURATION	b/D
□ N10 M4 R1	2.20
○ N10 M4 R6	1.80
△ N10 M5 R17	1.00

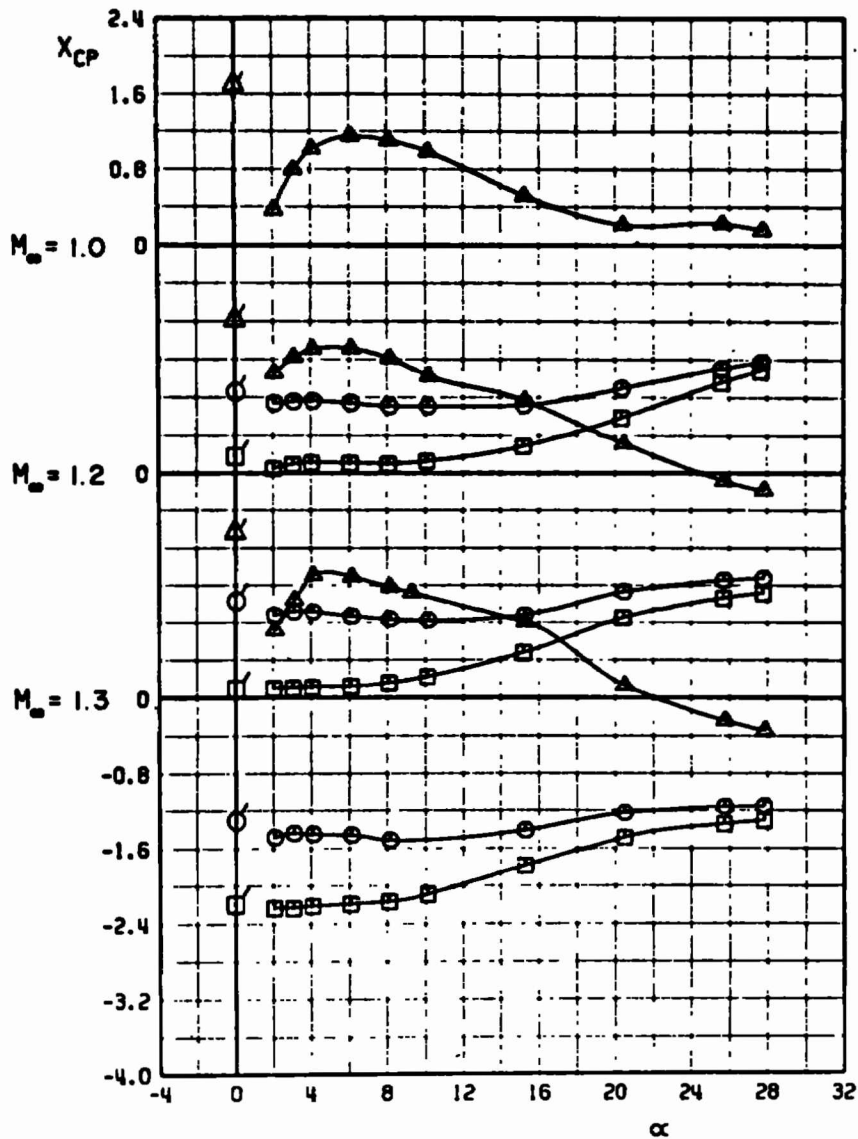
FLAGGED SYMBOLS DENOTE NEUTRAL-POINT LOCATIONS



b.  $X_{CP}$  versus  $\alpha$   
Fig. 11 Continued

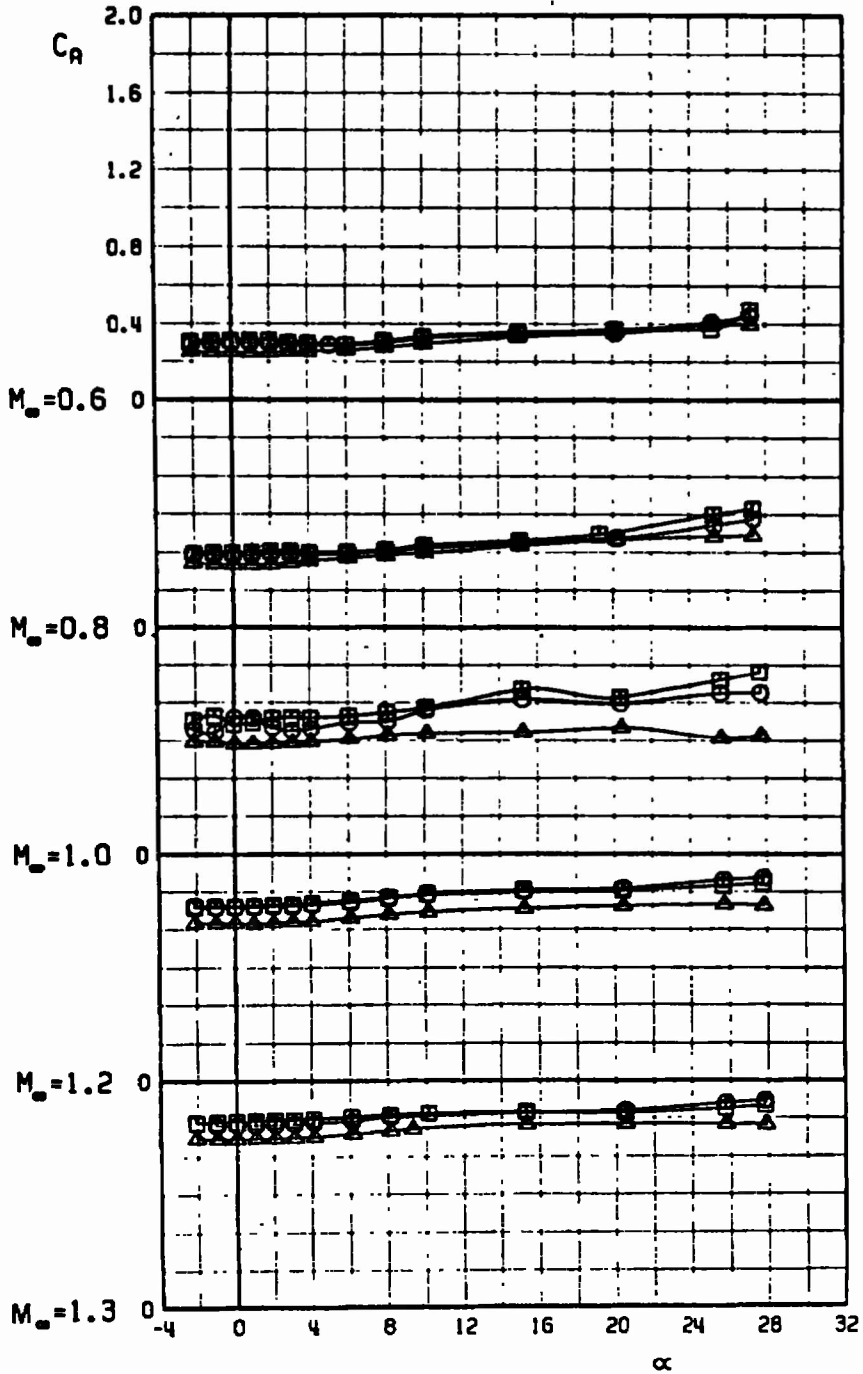
CONFIGURATION		b/D
□	N10 M4 R1	2.20
○	N10 M4 R6	1.80
△	N10 M5 R17	1.00

FLAGGED SYMBOLS DENOTE NEUTRAL-POINT LOCATIONS



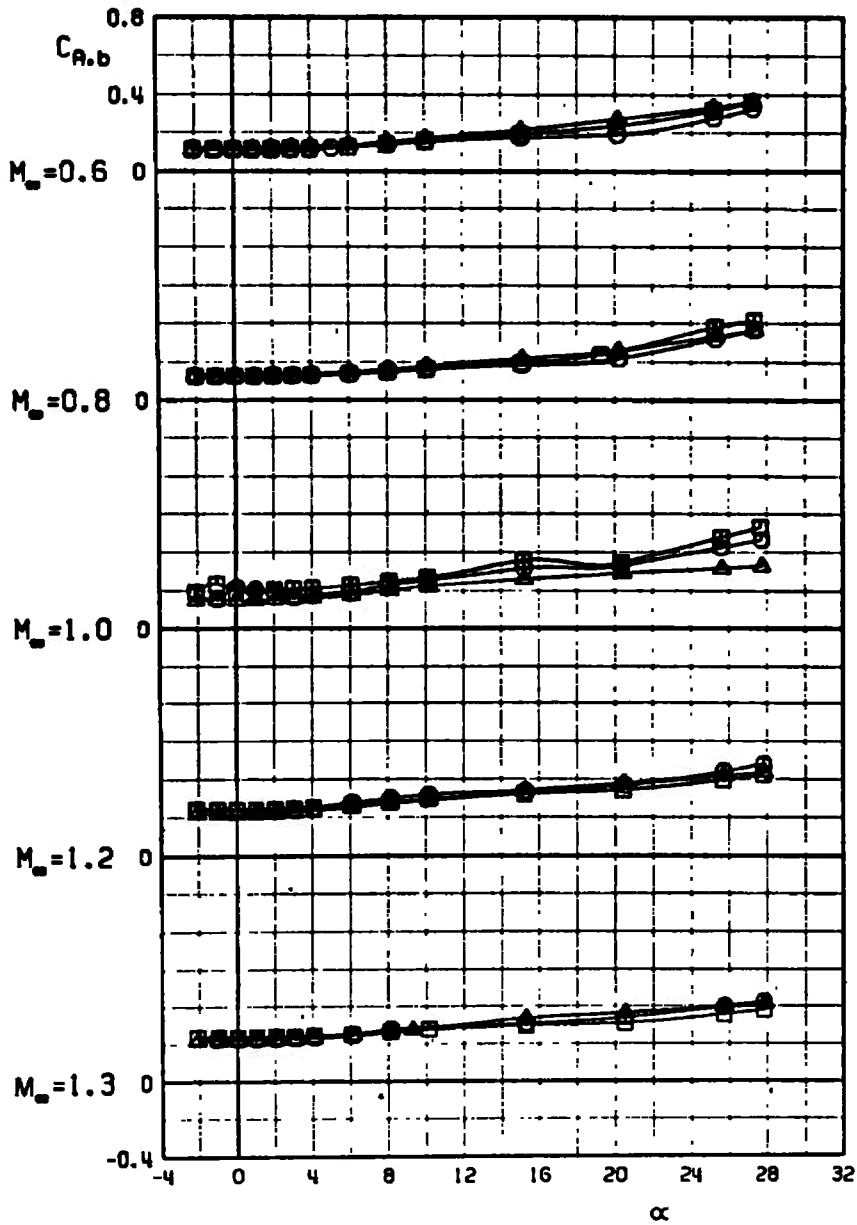
b. Concluded  
Fig. 11 Continued

CONFIGURATION			b/D
□	N10 M4 R1		2.20
○	N10 M4 R6		1.80
△	N10 M5 R17		1.00



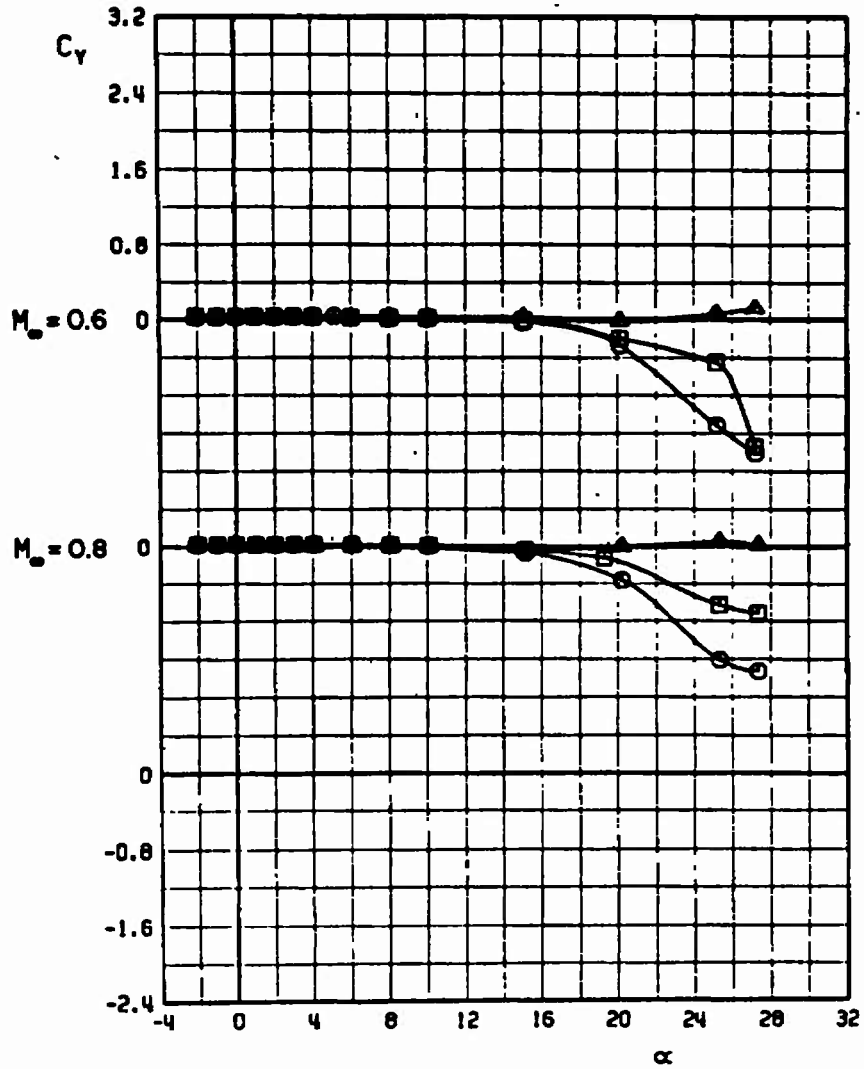
c.  $C_A$  versus  $\alpha$   
 Fig. 11 Continued

CONFIGURATION	b/D
□ N10 M4 R1	2.20
○ N10 M4 R6	1.80
△ N10 M5 R17	1.00



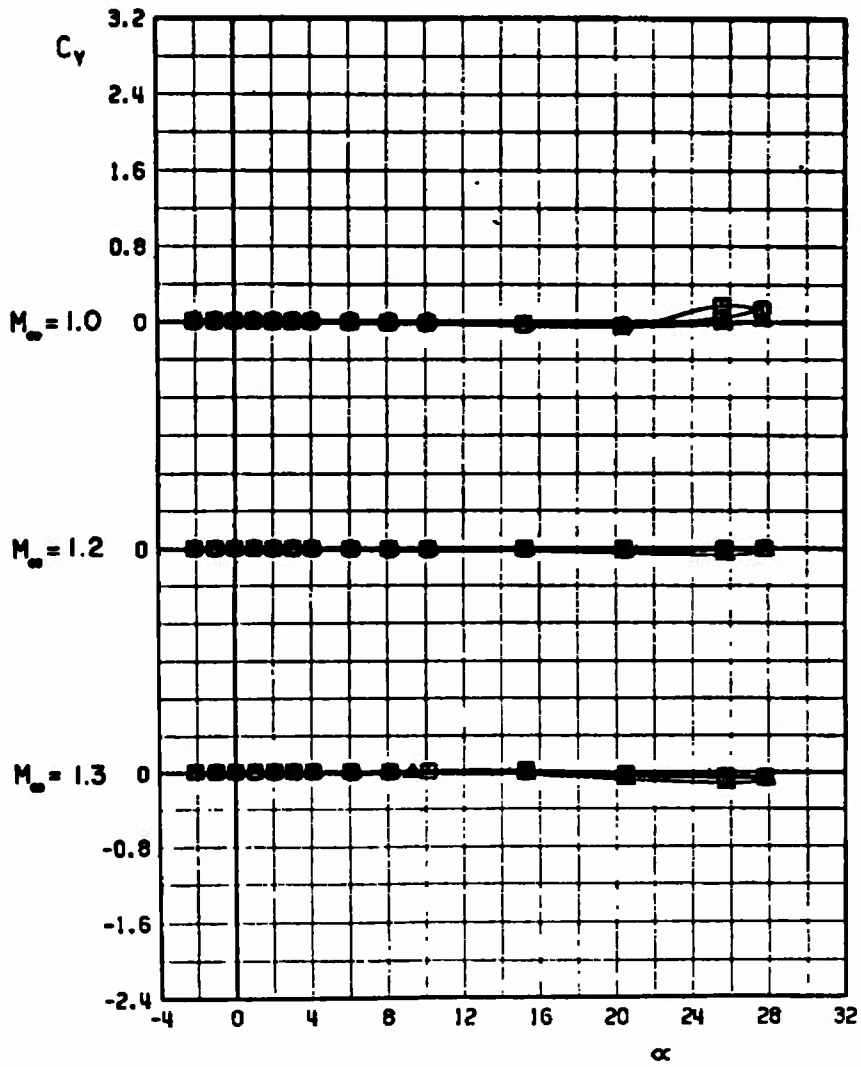
d.  $C_{A,b}$  versus  $\alpha$   
 Fig. 11 Continued

	CONFIGURATION	b/D
□	N10 M4 A1	2.20
○	N10 M4 A6	1.80
△	N10 M5 A17	1.00



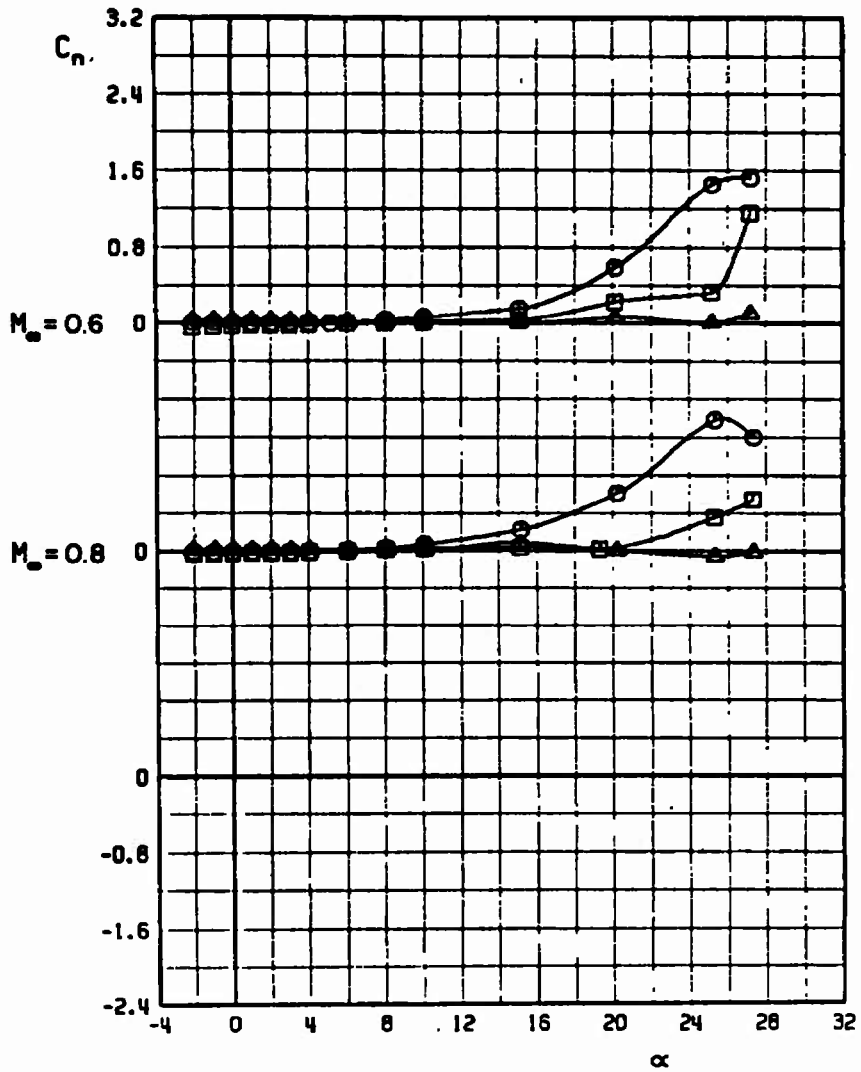
e.  $C_y$  versus  $\alpha$   
 Fig. 11 Continued

	CONFIGURATION	b/D
□	N10 M4 A1	2.20
○	N10 M4 A6	1.80
△	N10 M5 A17	1.00



e. Concluded  
Fig. 11 Continued

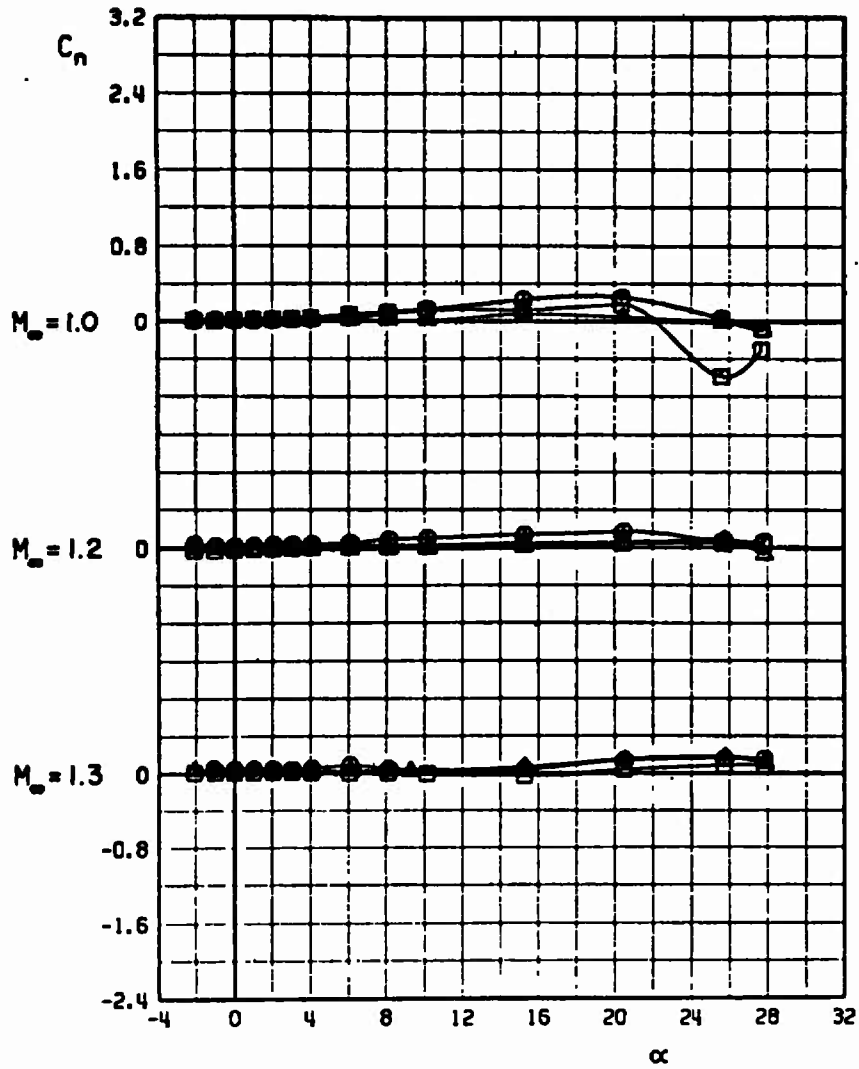
	CONFIGURATION	b/D
□	N10 M4 R1	2.20
○	N10 M4 R6	1.80
△	N10 M5 R17	1.00



f.  $C_n$  versus  $\alpha$   
 Fig. 11 Continued



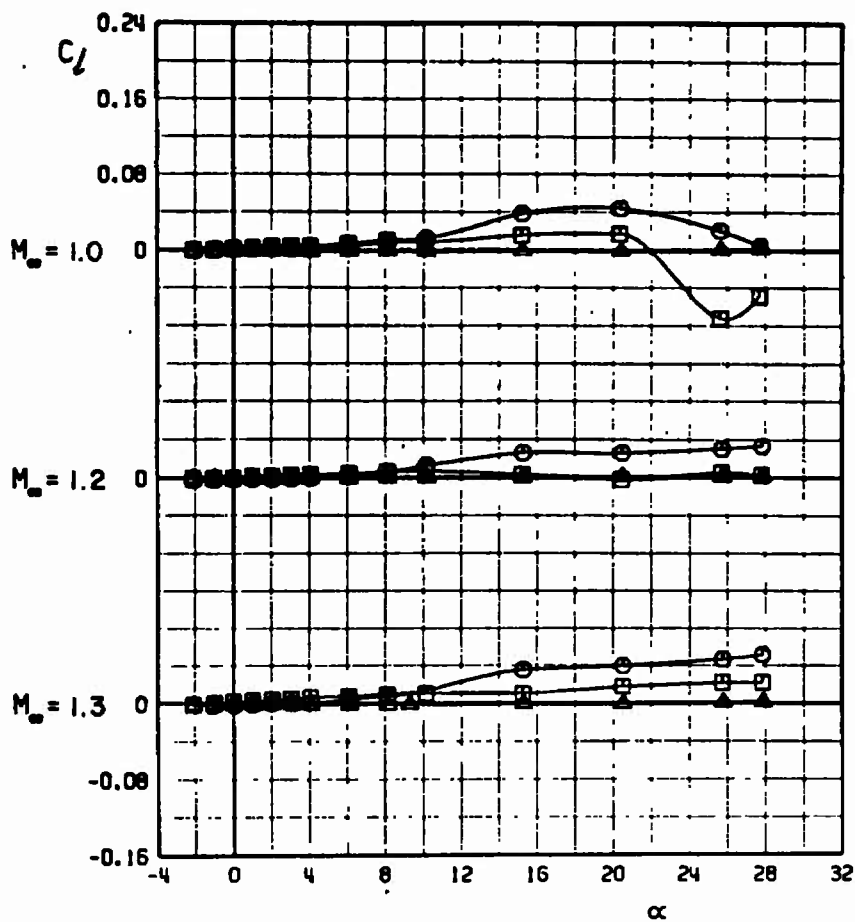
	CONFIGURATION	b/D
□	N10 M4 A1	2.20
○	N10 M4 A6	1.80
△	N10 M5 A17	1.00



f. Concluded  
 Fig. 11 Continued



	CONFIGURATION	b/D
□	N10 M4 R1	2.20
○	N10 M4 R6	1.80
△	N10 M5 R17	1.00



g. Concluded  
 Fig. 11 Concluded

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13. ABSTRACT An investigation was conducted in the Aerodynamic Wind Tunnel (4T) to obtain the static stability characteristics of a bluff body shape with various afterbody-stabilizer configurations. Data are presented for a Mach number range from 0.6 to 1.3 over an angle-of-attack range from -2 to 28 deg. For all configurations tested, it was found that the static margin was greatest for the configurations having the largest span swept and unswept blade-type fins.  Distribution limited to U.S. Government agencies only; this report contains information on test and evaluation of military hardware; May 1972; other requests for this document must be referred to Air Force Armament Laboratory (DLGC), Eglin AFB, FL 32542.			

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
aircraft external stores						
missiles						
tail assemblies						
bluff body						
static stability						
transonic wind tunnels						

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